COMMONWEALTH OF MASSACHUSETTS

INNER BELT AND EXPRESSWAY SYSTEM

BOSTON METROPOLITAN AREA

1962

COMMONWEALTH OF MASSACHUSETTS

JOHN A. VOLPE, GOVERNOR

INNER BELT AND EXPRESSWAY SYSTEM

BOSTON METROPOLITAN AREA

1962

PREPARED FOR THE

MASSACHUSETTS DEPARTMENT OF PUBLIC WORKS

JACK P. RICCIARDI, COMMISSIONER

IN COOPERATION WITH

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

A JOINT VENTURE REPORT BY

HAYDEN, HARDING & BUCHANAN, INC. AND CHARLES A. MAGUIRE & ASSOCIATES

CONSULTING ENGINEERS

Boston, Massachusetts

Mass Department of [illegible]
Sept. 6 1962

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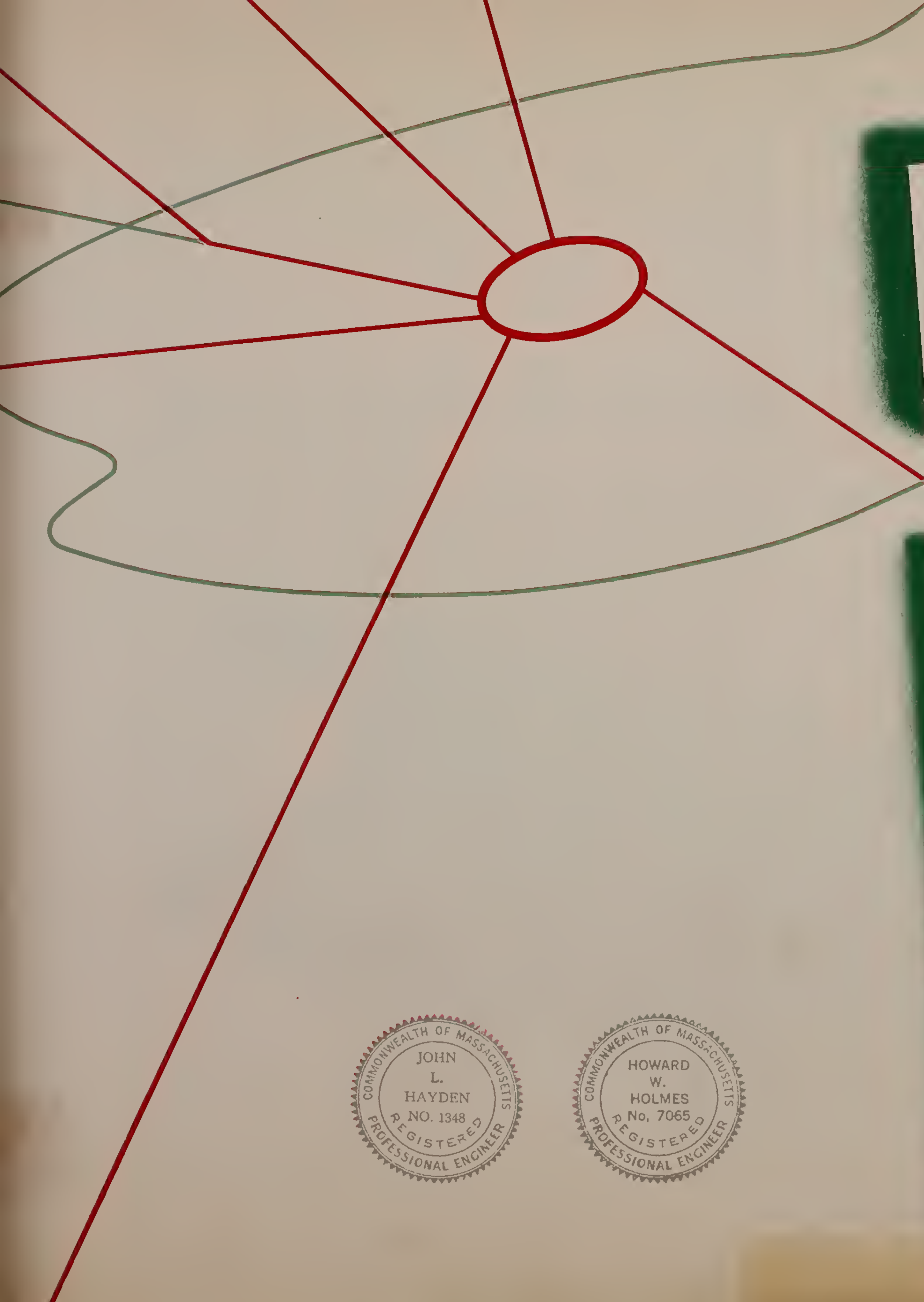

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June 15, 1962

Mr. Jack P. Ricciardi, Commissioner
Massachusetts Department of Public Works
100 Nashua Street
Boston, Massachusetts

Dear Mr. Ricciardi:

We are pleased to submit herewith our FINAL REPORT on the "INNER BELT AND EXPRESSWAY SYSTEM" for the Boston Metropolitan Area. The planning and location studies were undertaken in accordance with the Agreement dated June 2, 1959.

The Studies have presented numerous challenging problems which, through extensive research, have resulted in the development of advanced techniques unknown to the conventional procedures employed in expressway location studies.

We have developed Recommended Locations for the Inner Belt and Expressway System which we are confident will furnish the best traffic service in consonance with economic and other planning considerations to satisfy the present conditions and needs as well as those projected to 1975. We have also developed Alternate Locations for the Inner Belt and Expressway System.

Respectfully,

Hayden, Harding & Buchanan, Inc.

John L. Hayden

John L. Hayden

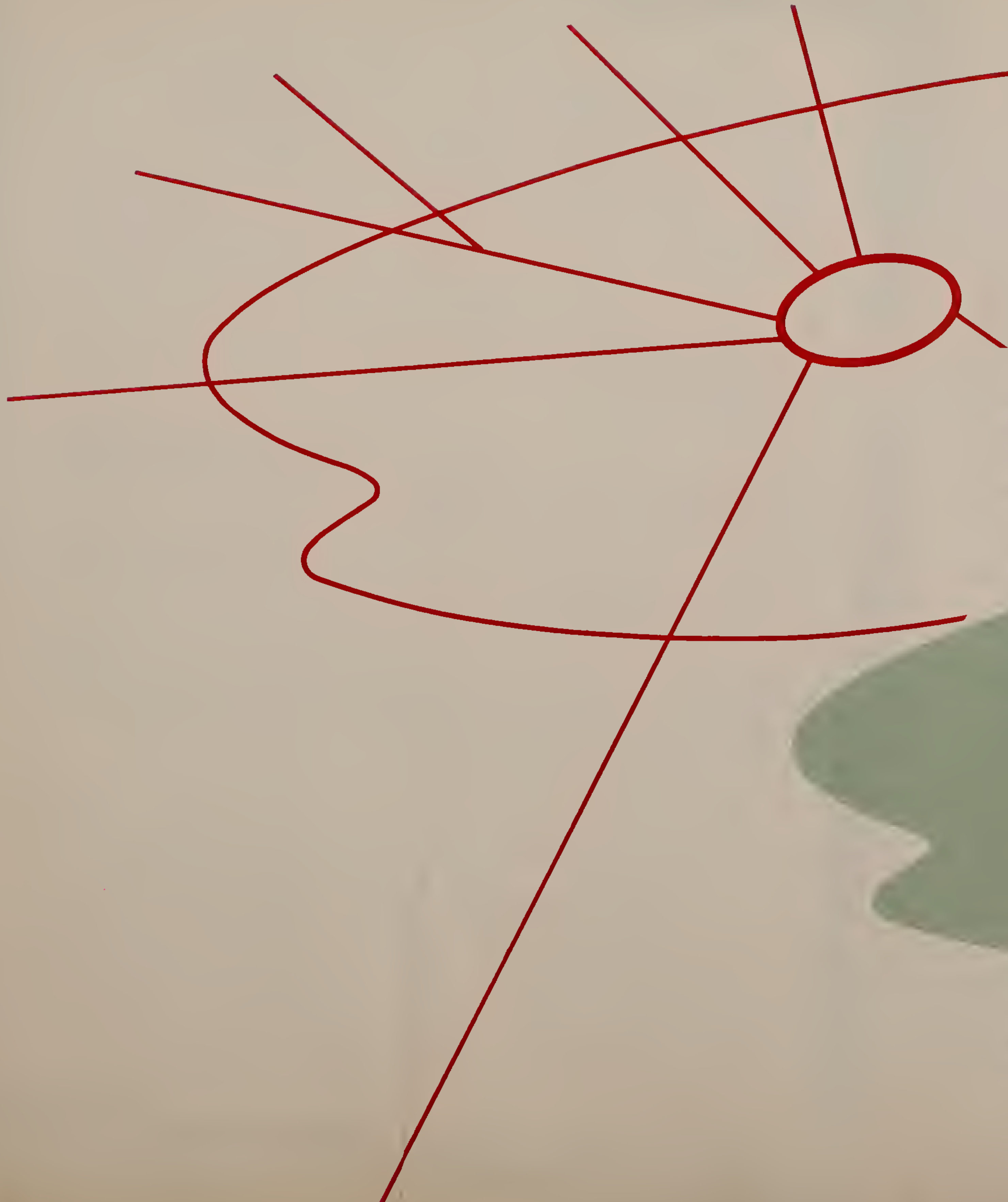
Charles A. Maguire & Associates

Howard W. Holmes

Howard W. Holmes

JLH/HWH/bfm

Joint Venturers . . . . Massachusetts Department of Public Works Contract
Boston Inner Belt And Expressway Connections



ACKNOWLEDGMENTS

The advice and assistance provided by the administrative and technical staffs of the Massachusetts Department of Public Works and the Bureau of Public Roads of the United States Department of Commerce are gratefully acknowledged.

For their cooperation in the compilation of detailed data, deep appreciation is expressed to the numerous officials and personnel of the 121 municipalities within the Study Area and particularly to those in the 13 cities and towns in which either the Recommended or Alternate Location of the Inner Belt and Expressway System are located. These 13 cities and towns are:

Arlington	Burlington	Milton
Belmont	Cambridge	Somerville
Boston	Canton	Winchester
Brookline	Lexington	Woburn
	Medford	

Representatives of the many civic groups and associations, educational institutions and public utilities as well as federal and state agencies also were extremely helpful and merit sincere appreciation for their cooperation.

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GLOSSARY

AASHO:
The American Association of State Highway Officials.

ADT:
Average Daily Traffic, the average two-way twenty-four-hour traffic volume for the stated year.

ALL-OR-NONE:
A reference to the traffic assignment procedure by which all trips of a given trip transfer are assigned to the shortest path and none to any alternate path.

ASSIGNMENT MODEL:
A mathematical model of the traffic assignment process, stated in mathematical terms primarily for computer application.

BASE YEAR:
The year of record upon which predictions of future traffic are based; in this Study the base year is 1959.

BOSTON METROPOLITAN AREA:
A general term referring to the area which includes the City of Boston and the complex of surrounding urban and suburban communities.

BUREAU or BPR:
The Bureau of Public Roads of the United States Department of Commerce.

CAPACITY:
The maximum number of passenger cars that can pass a given point on a lane or roadway during a stipulated time period under stipulated roadway and traffic conditions.

CAPACITY RESTRAINT:
A capacity stipulated for the assignment procedure for each expressway section, as the maximum traffic volume which may be assigned to that section under acceptable operating conditions for design purposes.

CENTRAL ARTERY:
The expressway through downtown Boston from City Square in Charlestown to Massachusetts Avenue in Roxbury, connecting the Northeast and Southeast Expressways; officially named the John F. Fitzgerald Expressway and designated as Interstate Route 95.

CENTRAL BUSINESS DISTRICT or CBD:
That part of the Boston Metropolitan Area in the City of Boston, bounded on the north by the Charles River, on the east by Boston Harbor, on the south by Fort Point Channel and South Bay, and on the west by Massachusetts Avenue.

CENTROID:
The weighted center of social and economic activity of a zone or sector; a node which represents this center in the network.

CORE AREA:
That part of the Boston Metropolitan Area in which is found the greatest density of social and economic activity; it includes the Central Business District and parts of South Boston, East Boston, Charlestown, Brookline, Cambridge, Somerville, Everett, and Chelsea.

CORDON LINE:
A line which circumscribes the CBD and at which traffic counts are surveyed or computed for comparison of traffic entering and leaving the area enclosed by the cordon-line.

DADT:
Directional Average Daily Traffic, the average one-way volume of traffic which occurs on a facility in a 24-hour period.

DDHV:
Directional Design Hour Volume, the one-way volume of vehicles per hour for which a facility is designed.

DEPARTMENT or DPW:
Massachusetts Department of Public Works.

DESIGN CAPACITY:
The volume of traffic in vehicles per day which a facility is designed to carry under acceptable operating conditions.

DESIGN YEAR:
The future year for which traffic volumes are predicted to serve as a basis for design; in this Study the design year is 1975.

DHV:
Design Hourly Volume, the two-way volume of traffic for which a facility is designed, in vehicles per hour; the thirtieth highest hourly volume of the year; in urban areas, the larger peak hourly volume of the day.

DOWNTOWN BOSTON:
The Central Business District.

FAIR MARKET VALUE:
The price of a property at which a well-informed buyer is willing to purchase, and well-informed owner is willing to sell.

FORTRAN:
The IBM language developed to ease communication between man and computer; an acronym for FORmula TRANslation.

FREE ASSIGNMENT:
The traffic assignment to a highway facility resulting from unqualified use of the all-or-none assignment procedure.

GRAVITY MODEL:
A mathematical model of interactions in which the distribution functions vary as an inverse power of a distance measurement. Two such gravity models were used for this Study: one for the distribution of trips in Traffic Analysis, Part III, and one for the distribution of population and employment in Socio-Economic Analysis, Part IV.

INNER BELT:
The 1948 Master Highway Plan proposed the concept of the Belt Route as the entire inner circumferential expressway for the core area of Metropolitan Boston. The downtown portion of the Belt Route was called the Central Artery and is so referred to herein. The balance of the Belt Route, from the Southeast Expressway westerly and northerly to the Northeast Expressway, is referred to as the Inner Belt. Under the National System of Interstate and Defense Highways the Southwest Expressway, a section of the Inner Belt from the Southwest Expressway to the Central Artery, the Central Artery and the Northeast Expressway are designated as Interstate Route 95; the Inner Belt from the Southwest Expressway westerly and northerly through Boston, across the Charles River through Cambridge, Somerville and the Charlestown section of Boston to an interchange with the Northeast Expressway, is designated as Interstate Route 695.

INTERCHANGE:
A grade-separated intersection with one or more roadways, or ramps, which will permit transfer of vehicles between the intersecting roadways; a set of expressway access and corresponding egress ramps for a local street(s) or the direct connectors providing an interchange between major expressways.

INTERSTATE ROUTE 90:
The Massachusetts Turnpike and Turnpike Extension to the Inner Belt. That part of the Extension between the Inner Belt and the Central Artery is not part of the Interstate System.

INTERSTATE ROUTE 93:
The Northern Expressway from the Inner Belt northerly to Route 128, thence through Massachusetts and Central New Hampshire to St. Johnsbury, Vt.

INTERSTATE ROUTE 95:
Serves the eastern seaboard of the U. S. from Miami, Florida, to Houlton, Maine. The Southwest Expressway, the Inner Belt from the Southwest Expressway to the Central Artery, the Central Artery, and the Northeast Expressway are designated as Interstate Route 95 in the Boston area.

INTERSTATE ROUTE 695:
The Inner Belt from the Southwest Expressway (I-95) westerly and northerly through Boston, Cambridge and Somerville to the Northeast Expressway (I-95).

ISOCHRONE:
A line drawn on a map through all points which have equal travel times from a common point of origin called the isochrone-center; a travel-time contour.

LINK:
A unidirectional straight line connecting two nodes in a network to represent a portion of a highway system; it may be used in one-to-one correspondence with a street in the system, or in many-to-one correspondence to represent a group of parallel streets.

MATHEMATICAL MODEL:
A model in which the functions or operations of the prototype are represented by a mathematical equation or series of equations.

MATHEMATICAL MODEL SYSTEM:
A series of mutually compatible and interdependent mathematical models.

MATRIX:
A table listing the trip transfers and their volumes between each station, zone or sector and each other station, zone or sector in an urban area.

M.D.C.:
The Metropolitan District Commission.

MINIMUM TIME PATH:
The route from one point to another through a network for which the travel time is smallest.

M.T.A. (MTA):
The Metropolitan Transit Authority.

NETWORK:
A skeletonized representation of an urban street and highway system, consisting of nodes connected by straight-line links.

NODE:
A point of intersection of links of a network; such nodes may be used to represent a variety of situations in the real highway system.

O. & D.:
Origin and Destination, referring to a surveyed or computed matrix, or table, of the volume of traffic which travels from each zone to each other zone in an urban area.

O. & D. SURVEY:
A field survey to determine the volume of traffic originating in or destined for each zone in the survey area.

PARAMETER:
A quantity in a mathematical equation to which may be assigned arbitrary values; two types of parameters are referred to herein:

a. Fitting parameters, for the purpose of correlating computed results with surveyed or measured data; subsequent to such correlation, the values found became constants.
b. Socio-economic parameters, which vary from year to year in the traffic analysis.

ROUTE:
See Interstate Route or State Route.

SCREEN-LINE:
A line described across an urban area, isolating a portion of that area, for the purpose of measuring or comparing traffic volumes crossing this line. Traffic crossing this line is known as the screen-line volume.

SECTOR:
A subdivision of a zone, established to obtain more detailed information than obtainable from the zone.

SOCIO-ECONOMIC STUDY AREA:
The group of 121 cities and towns generally within the area bounded by Interstate Route 495, as shown on Exhibit S-1.

SPIDER NET:
A complete set of nodes and links representing the highway system of an urban area; a network.

STANDARD METROPOLITAN AREA:
The group of 65 cities and towns which comprise the Boston Standard Metropolitan Statistical Area as established by the 1950 Census of the U. S. Department of Commerce, Bureau of Census; the traffic analysis was based on this area.

STATE ROUTE 2:
The Northwest Expressway from the Inner Belt in Cambridge and Somerville to Alewife Brook Parkway, thence along existing Route 2 to Route 128 and thence to the New York State line; a part of the Federal-Aid Primary Highway System.

STATE ROUTE 3:
From the New Hampshire line near Nashua to Route 128 in Burlington, thence to a connection with either the Northwest or the Northern Expressway; a part of the Federal-Aid Primary Highway System.

TERMINAL TIME:
Time spent at the start of a trip in getting a motor vehicle on the road, or at the end of a trip in locating and occupying a parking place.

TISRO:
Acronym of the TIme-Saving-Rank-Order method of traffic assignment.

TISRO ASSIGNMENT:
A modified all-or-none method of assignment in which trip transfer volumes are assigned to a network in order of their potential time-savings via the expressway, from greatest to smallest.

TRAFFIC STUDY AREA:
The 65 cities and towns of the 1950 Boston Standard Metropolitan Statistical Area.

TREE:
The set of minimum-time paths from any given node to all other nodes in a network.

TRIP TRANSFER:
A traffic movement from a specific zone, sector or station of origin to a specific destination; a position in the O. & D. matrix.

TRIP TRANSFER VOLUME:
The average daily traffic volume of a trip transfer; an interzonal volume.

ZONE:
A sub-area of the Traffic Study Area, established to represent a logical grouping of traffic generators and attractors. A zone may be either a sub-division of a city or town, or one or more towns.

FOREWORD

The opening of the final section of the Central Artery (John F. Fitzgerald Expressway) on June 25, 1959, was an important milestone in a thirty-year effort to provide safe and efficient traffic service for this area and signalled the beginning of a new era for the Boston Metropolitan Area. The Mystic River Bridge, the East Boston Expressway, Route 128, the Southeast Expressway, the Northeast Expressway, the Callahan Tunnel, and Interstate Route 93 represent many important miles of the Expressway System which have been either completed or started within the last fifteen years. The large traffic volumes attracted to the completed parts of the system clearly demonstrate the immediate need for the early completion of the remaining expressways, and the necessity for continuous study of improvements to the transportation system, since traffic movements and highway location are influenced by constant changes in land use and population migrations.

In accordance with the Agreement with the Commonwealth of Massachusetts, the purpose of this Study was the preparation of planning and location studies and the presentation of recommended basic design for certain remaining parts of the Expressway System. Specifically mentioned for study in this Agreement were the following:

1. The proposed Inner Belt Expressway, from the vicinity of the Prison Point Bridge in the Charlestown section of Boston, thence passing through Somerville, Cambridge, Brookline, and Boston and terminating at the southerly end of the present Central Artery in the Roxbury section of Boston.
2. The proposed Southwest Expressway from Route 128 in Canton, thence extending northerly through Boston to a connection with the proposed Inner Belt Expressway in the Roxbury section of Boston.
3. The proposed Northwest Expressway from the vicinity of the intersection of Concord Turnpike and Alewife Brook Parkway in Cambridge, thence through Cambridge and Somerville to a connection with the proposed Inner Belt Expressway in Cambridge.
4. The proposed Northern Expressway from the present terminus at Mystic Valley Parkway in Medford, thence through Medford and Somerville to a connection with the proposed Inner Belt Expressway in Somerville.
5. The Route 3 Expressway from the present terminus at Route 128 in Burlington extending southerly to integrate with the proposed Expressway System.
6. The junction of the proposed Massachusetts Turnpike Extension with the proposed Inner Belt Expressway.

In connection with this latter requirement, it was not until early 1962 that the exact status of the Turnpike was finally established. Meanwhile, it became necessary to forecast traffic in this Study to include traffic assignments for an expressway to the west, both as a free and as a toll facility, in order to provide data for either alternative.

The scope and objectives of this Study of the Inner Belt and Expressway System involved the following:

- Study of traffic desires in 65 communities of the Boston Metropolitan Area in determination of realistically projected 1975 design volumes of traffic which may be expected on the Inner Belt and Expressway System, including interchange ramps.

- Study of social and economic effects attributable to the proposed Inner Belt and Expressway System in 121 communities comprising the Economic Study Area including estimates of future population, employment, economic development and community benefits realized from the Expressway System.

- Study of pertinent engineering and economic data in preparation of basic designs, estimates of the cost of construction, estimates of the cost of acquisition of right-of-way, and road-user benefits.

- Study of alternative locations for the Inner Belt and Expressway System in consideration of the above data.

- Development and presentation of the basic design of the Recommended and Alternate Locations for the Inner Belt and Expressway System.

The basic concept of the Expressway System is publicly accepted, and the projected desires and the engineering data gathered during the course of this Study clearly indicate the need for the Expressway System as well as other improvements in the transportation system.

Continuous liaison was maintained with officials and interested citizen groups of the cities and towns in the Study Area to obtain their constructive criticism and comments. Public hearings were held in Boston and Cambridge in the spring of 1960 to permit the general public to voice their opinions concerning location of the Inner Belt and the Northern Expressway.

The selection of the Recommended and Alternate Locations for the various expressways was unusually complex due to the heterogeneous character of development of the Study Area. Therefore, in order to develop feasible locations for each expressway, it was necessary to establish detailed engineering data pertinent to each alternative, to analyze the advantageous and disadvantageous short and long-range effects, and to develop factual comparisons essential to the selection of expressway locations. This was done with the utmost care.

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Since the inevitably changing conditions of a dynamic economy have a continuing impact on the selection of expressway locations, January 1, 1962 was established as the limiting date for consideration of factors that might affect the recommendations contained herein.


ROUTE 3 EXPRESSWAY
NORTHERN EXPRESSWAY
NORTHEAST EXPRESSWAY
ROUTE 2
NORTHWEST EXPRESSWAY
ROUTE 128
MASSACHUSETTS TURNPIKE EXTENSION
INNER BELT
SOUTHEAST EXPRESSWAY
SOUTHWEST EXPRESSWAY
ROUTE 128
W. McTammany, Del. 1962

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The vigorous industrial, commercial, governmental, and residential development currently in progress in the Boston Metropolitan Area dramatizes the need to accelerate the completion of the Inner Belt and Expressway System. The traffic volume generated by this vigorous growth, witnessed by the congestion on the present network of roads and streets leading to and within the Boston Metropolitan Area, is forceful evidence that the completion of the Expressway System must receive the highest priority in the highway program of the Commonwealth.

Predicted increases of 270,000 in population, 70,000 in employment and 280,000 in motor vehicle registration within sixty-five communities of the Boston Metropolitan Area by the year 1975, accentuated by the current vigorous rebirth of the Core Area and the concurrent rapid growth of suburban areas, are indisputable testimony that augmented and improved transportation facilities are vitally needed. The philosophy of an Inner Belt and Radial Expressway System was presented in the *Master Highway Plan for the Boston Metropolitan Area* in 1948, and was adopted by the Commonwealth as the basis for a long-range program of highway improvements. This Study reaffirms the validity of an Inner Belt and Radial Expressway concept and the urgency for early completion of the Expressway System.

The Central Artery, the Southeast Expressway, the Northeast Expressway, and a portion of the Northern Expressway were completed as the initial phase of this long-range program. Developments which have occurred, including the construction of these sections of the Master Highway Plan, have had a profound effect on the traffic pattern of the Metropolitan Area, far beyond that anticipated at the time of the 1948 Study. Significant changes in the locations of the Inner Belt and the Expressways recommended herein, as compared with earlier studies, have resulted from shifting and rapidly expanding population and employment, increased use of motor vehicles, striking changes in land-use patterns, decline of mass transit patronage and railroad service, and construction of expressways, together with technological advances in highway planning and a more comprehensive understanding of the complex principles of traffic movements.

The Government Center Project in the Scollay Square Area, with city, state, and federal office buildings, the Prudential Center Project, the New York Streets Project, the West End Project, the Whitney Street Project, the North Harvard Project, the 350-acre industrial development site in the lower Roxbury Area, the Washington Park Renewal Area, the 71-acre site at Donnelly Field, the Houghton Renewal Area, the 160-acre Cambridgeport Renewal Area, the Massachusetts Institute of Technology Research Center, and the 60-acre project in the Linwood-Jay Area, are prime illustrations, within the Core Area, of changes in land-use patterns, population shifts, and employment potentials in expression of the theme of expansion of the mid-twentieth century.

The suburban areas have also experienced industrial and residential development in the past ten years, beyond the imagination of the most hopeful planners. This growth pattern, which has received world-wide recognition, was due primarily to the ambitious construction of Route 128, the first circumferential expressway for Metropolitan Boston.

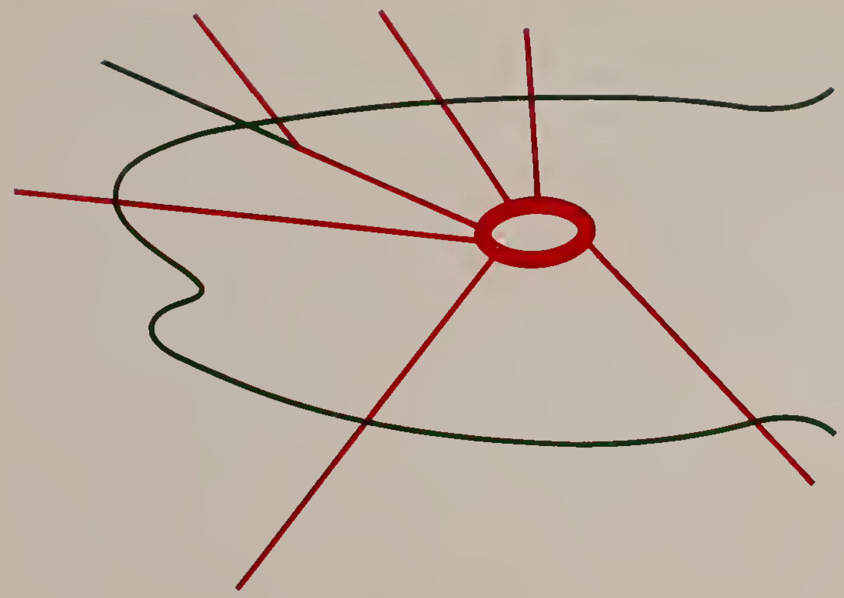
This dramatic revitalization of the core area, this imaginative development of the suburban areas, this collective mood of confident expansion characteristic of the Boston Metropolitan Area, is strong evidence of the desire of an enthusiastic populace to realize the full potential of their region. An intelligently planned and executed system of coordinated transportation media, responsive to the needs of both the present and the future will result in a vigorous regional economic growth. In order to develop such a system, it is imperative that the same bold steps be taken that have been taken in the renewal of the core and suburban areas and in the development of the Expressway System.

In addition to new expressways, the necessity for an expanded, modernized and attractive public transit system integrated with all passenger transportation facilities is fully recognized. Such a system would provide an economical and rapid form of transportation in the urban area, and would greatly reduce street and highway congestion by serving large numbers of passengers in relation to the space required. Areas of concentrated economic activity would be integrated with the Core Area by the continuity of a coordinated mass transportation and expressway system, capable of serving the requirements of the Boston Metropolitan Area.

A vital component of the integrated transportation system is an expressway system for the movement of large numbers of passenger and commercial vehicles within and through the core and suburban areas. The authorization and direction of this Study by responsible federal and state agencies resulted in a concentrated and coordinated effort to analyze all related factors, in order to provide the best solution for the expressway component of the transportation system. The complex of studies directed toward this need produced many alternative locations for the Inner Belt and Expressway System. A comparative evaluation of these alternatives resulted in the selection of those locations which will best serve the entire area. These locations have been designated as the Recommended and Alternate Locations, and the expressways, built in the Recommended Locations, will act as a continuing stimulus to the economy of the area, and will best serve as part of the Interstate and Defense Highway System. The Recommended Locations place the facilities where they best serve the major traffic desires with the highest possible degree of service. The Alternate Locations provide an adequate but less satisfactory solution, in weighted consideration of numerous complex factors upon which the selection of locations was made.

Conclusive evidence exists that the completed Expressway System will provide manifold benefits for the Boston Metropolitan Area. To realize the full potential of the Expressway System, vigorous coordinated action between Federal and State Governments and the communities of the Boston Metropolitan Area is necessary. The displacement of businesses and residences resulting from urban renewal projects and expressway projects should be planned in unison and in consideration of the absorptive capacity of existing and proposed facilities. Coordinated planning presents an opportunity to work together to achieve the mutually beneficial goal of completing the vitally-needed Expressway System, and at the same time realizing the planning objectives of the individual communities.

In sum, the achievement of the Inner Belt and Expressway System, carefully integrated with a comprehensive transportation plan and the many public and private developments now proceeding, will earn the Boston Metropolitan Area the right to valid anticipation of a continuing position of prominence among the urban regions of the United States.



RECOMMENDED INNER BELT AND EXPRESSWAY LOCATIONS

The comparative service, features and costs of the Recommended Location of the Inner Belt and Expressway System are presented in detail in Part V; however, for convenience of reference, a short summary of applicable costs for the Recommended Locations is included here.

INNER BELT EXPRESSWAY
(I-695 and Section of I-95)

The Recommended Location of the Inner Belt Expressway extends from the southerly end of the Central Artery, near Massachusetts Avenue, by way of Ruggles Street and the Fenway in Boston, to a double-deck bridge across the Charles River, parallels Brookline and Elm Streets in Cambridge, enters the Boston & Maine Railroad Yard in Somerville and Boston, and terminates in the vicinity of Prison Point Bridge at the end of a section of the Inner Belt for which the design has been completed.

Estimated Construction Cost	$144,793,000
Estimated Right-of-Way Cost	$ 24,025,000
Total Cost	$168,818,000

SOUTHWEST EXPRESSWAY
(Interstate Route 95)

The Recommended Location of the Southwest Expressway extends from Route 128 in Canton by way of the Neponset Valley Reservation to Readville, crosses to the west of and parallel to the New York, New Haven & Hartford Railroad to Jackson Square in Roxbury where it recrosses the railroad to an interchange with the Recommended Location of the Inner Belt at Madison Park in Boston.

Estimated Construction Cost	$ 48,296,000
Estimated Right-of-Way Cost	$ 16,092,000
Total Cost	$ 64,388,000

ROUTE 3 EXPRESSWAY

The Recommended Location of the Route 3 Expressway extends from Route 128 in Burlington by way of Great Meadow in Lexington, to existing Route 2 at Appleton Street, then follows existing Route 2 to Alewife Brook Parkway in Cambridge, where it joins the Northwest Expressway.

Estimated Construction Cost	$ 27,080,000
Estimated Right-of-Way Cost	$ 6,034,000
Total Cost	$ 33,114,000

NORTHWEST EXPRESSWAY

The Recommended Location of the Northwest Expressway extends from the Recommended Route 3 Expressway at Alewife Brook Parkway in Cambridge by way of a line parallel to the Fitchburg Branch of the Boston & Maine Railroad, passing south of Porter Square, to an interchange with the Recommended Location of the Inner Belt in Cambridge.

Estimated Construction Cost	$ 34,567,000
Estimated Right-of-Way Cost	$ 5,886,000
Total Cost	$ 40,453,000

NORTHERN EXPRESSWAY
(Interstate Route 93)

The Recommended Location of the Northern Expressway extends from the end of the existing construction, at Mystic Valley Parkway in Medford, by way of Mystic Avenue to an interchange with the Recommended Location of the Inner Belt in the Boston & Maine Railroad yards in Somerville and Boston.

Estimated Construction Cost	$ 13,686,000
Estimated Right-of-Way Cost	$ 4,042,000
Total Cost	$ 17,728,000

ANNUAL ROAD-USER BENEFITS

Benefits will accrue to the users of the Expressway System as a result of reduced operating costs, reduced travel time, increased comfort and convenience, and a reduction of the accident rate, as compared with travel over existing streets between comparable points. Such benefits are referred to as "Road-User Benefits" and have been calculated on the basis of annual savings accruing to the users of each expressway of the system.

ANNUAL SAVINGS FOR THE ROAD-USER
(For the Recommended Location of Each Expressway)

Inner Belt	$43,883,000
Southwest Expressway	14,290,000
Route 3 Expressway	11,630,000
Northwest Expressway	12,403,000
Northern Expressway	4,029,000
Total Annual Savings	$86,235,000

These values show a total annual savings of $86 million per year for users of the Expressway System as compared with travel over existing streets.

CONSTRUCTION PROGRAM

The recommended construction schedule for the Inner Belt and Expressway System, is shown in Exhibit G-1 and is presented below together with project costs for the Recommended Locations. The schedule is based on the relative urgency of the traffic needs of the Boston Metropolitan Area with due regard for the construction of usable sections which provide the earliest relief from traffic congestion. Construction of the section of the Inner Belt from the interchange of the Central Artery with the Northeast Expressway, to Prison Point Bridge in Charlestown should commence in 1963. Its estimated cost, $8,223,000 is not included in the project cost given below.

		Project Cost
STAGE NO. 1 — Construction to Start 1963-1965		
Northern Expressway (I-93)	From the Mystic Valley Parkway (Route 16), Medford, to Foss Park, Somerville.	$ 5,156,000
Inner Belt (I-695)	From Prison Point Bridge to and including the Northern Expressway (I-93) interchange in Somerville.	$ 25,748,000
Inner Belt (I-695)	From Brookline Avenue to Soldiers Field Road, Boston, with connections to the extension of the Massachusetts Turnpike.	$ 30,541,000
Northern Expressway (I-93)	From Foss Park, Somerville, to the interchange with the Inner Belt in Somerville.	$ 12,572,000
	TOTAL COST OF STAGE NO. 1:	$ 74,017,000
STAGE NO. 2 — Construction to Start 1964-1966		
Inner Belt (I-95) & (I-695)	From Massachusetts Avenue to Columbus Avenue, Boston, and the Southwest Expressway to Jackson Square.	$ 29,593,000
Southwest Expressway (I-95)	From Route 128, Canton, to Forest Hills, Boston.	$ 41,119,000
Route 3 Expressway (Route 3 and Route 2 — Primary System)	From Appleton Street, Arlington, to Alewife Brook Parkway, Cambridge.	$ 14,790,000
	TOTAL COST OF STAGE NO. 2:	$ 85,502,000
STAGE NO. 3 — Construction to Start 1966-1968		
Inner Belt (I-695)	From the Northwest Expressway in Cambridge to the Northern Expressway in Somerville.	$ 33,166,000
Southwest Expressway (I-95)	From Forest Hills, Boston, to Jackson Square, Boston.	$ 23,269,000
Inner Belt (I-695)	From Soldiers Field Road, Boston, to and including the Northwest Expressway interchange.	$ 25,721,000
	TOTAL COST OF STAGE NO. 3:	$ 82,156,000
STAGE NO. 4 — Construction to Start 1967-1969		
Inner Belt (I-695)	From Columbus Avenue, Boston, to Brookline Avenue, Boston.	$ 24,049,000
Northwest Expressway (Route 2 — Primary System)	From Alewife Brook Parkway, Cambridge, to the interchange with the Inner Belt in Cambridge, including ramps to McGrath Highway.	$ 50,811,000
Route 3 Expressway (Route 3 — Primary System)	From Route 128, Burlington, to Route 2 at Appleton Street, Arlington.	$ 7,966,000
	TOTAL COST OF STAGE NO. 4:	$ 82,826,000
	TOTAL COST OF ALL STAGES:	$324,501,000

Exhibit G-1

EXPRESSWAY CONSTRUCTION SEQUENCE

SUMMARY OF RECOMMENDATIONS

It is recommended that:

The Inner Belt and Expressway System be constructed in the Recommended Locations, which best serve the vehicular traffic requirements of the Boston Metropolitan Area.

Particular attention be directed to the recommended construction schedule and every effort be expended to advance this schedule so as to provide relief from traffic congestion as early as practicable.

The design and construction of the Massachusetts Turnpike and Inner Belt connection be coordinated in order to achieve maximum benefit and economy of construction.

The Commonwealth take the necessary steps to provide an effective mass transportation system for the Boston Metropolitan Area that is coordinated and integrated with the Inner Belt and Expressway System.

A coordinated program of local street improvements be initiated in order to realize the full potential of the Expressway System.

The Commonwealth continue its study of the ever-changing factors influencing and dictating highway requirements.

The City of Boston continue its off-street parking program, and the cities of Cambridge and Somerville and the Town of Brookline initiate such programs integrated with the transportation system.

Additional study of the following major improvements be made so as to plan effectively to provide increased capacity for the Expressway System and the arterial streets:

1. Supplementation of the Central Artery by providing an additional expressway facility or a continuous surface arterial parallel to the Central Artery.
2. Construction of a direct connection from the Northeast Expressway to Leverett Circle.
3. Reconstruction of McGrath and O'Brien Highways to Leverett Circle.
4. The provision of additional lanes for the Southeast Expressway north from Columbia Circle.
5. Construction of direct connections from the Southeast Expressway into the South End Urban Renewal Area.
6. Construction of an intermediate circumferential highway which would utilize portions of Revere Beach, Mystic Valley, Alewife Brook and Fresh Pond Parkways, the proposed Charles River Parkway, Market Street, Chestnut Hill Avenue, the Arborway, Morton Street, and Gallivan Boulevard.

PART I

INTRODUCTION

SECTION 1 – GENERAL

OBJECTIVE

This Report presents the planning and location studies undertaken for the development of the Inner Belt and Expressway System for the Boston Metropolitan Area, consisting of the Inner Belt (Interstate Route 695), with a connection to the Massachusetts Turnpike Extension, and the following radial expressways: the Southwest Expressway (Interstate Route 95); the Northern Expressway (Interstate Route 93); and Federal Primary Highways Route 3 (southerly from Route 128) and the Northwest Expressway. The basic objective of these studies was to determine the best location for these expressways. Fundamental factors considered in location determinations were traffic desires, social and economic effects, neighborhood planning, topography, design criteria, military advantages, and related matters affecting the 65 communities of the Traffic Study Area and 121 communities of the Socio-Economic Study Area of this Report.

DESCRIPTION OF STUDY AREA

Boston, the cultural center of New England, is the hub of this Economic Study Area which extends south to Taunton, west to Marlborough and north to North Andover. The Mystic River, Charles River, and Neponset River have their sources near the outer fringes of the area and converge from the north, west, and south on Boston Harbor, where extensive port facilities have developed at the confluence of the harbor and the Mystic and Charles Rivers. The 1960 Federal Census for this area records a total population of approximately 3,200,000. As one of the country's major research, scientific, educational, medical, manufacturing, and shipping centers, opportunity for the employment of more than 1,200,000 is presently available.

The existing major surface streets of the Boston Metropolitan Area have the appearance of a giant spider web. The pattern consists essentially of four rings crossed by streets radiating from the Boston Central Business District. The innermost ring surrounding the business district consists of Commercial Street, Atlantic Avenue, Kneeland and Stuart Streets, Charles Street, Nashua Street, and Causeway Street. The second ring is formed by Columbia Road starting at Pleasure Bay on the southwest shore of Boston Harbor, and thence along Massachusetts Avenue, Memorial Drive, and the Prison Point Bridge to Charlestown. This ring links South Boston, Back Bay, and the Charlestown areas. The third ring is made up of a combination of boulevards and major streets starting at Neponset Circle, south of Boston, and consists of Gallivan Boulevard, Morton Street, the Arborway, Jamaicaway, Harvard Street, Boylston Street, Kirkland Street and Washington Street. The outermost ring is formed by the Neponset Valley, Turtle Pond, West Roxbury, Hammond Pond, Fresh Pond, Alewife Brook, Mystic Valley and Revere Beach Parkways. Radiating from the central core and intersecting those rings, are Dorchester Avenue, Morrissey Boulevard, Blue Hill Avenue, Hyde Park Avenue, Washington Street, Veterans of Foreign Wars Parkway, Route 9, Huntington Avenue, Beacon Street, Commonwealth Avenue, Soldiers Field Road, Storrow Drive, Massachusetts Avenue, Broadway, Cambridge Street, McGrath Highway, and Rutherford Avenue.

EXPRESSWAY SYSTEM

The problem of traffic congestion in the Boston Metropolitan Area has been the subject of many studies in previous years by various public agencies and civic groups. The first comprehensive report on the problem of traffic congestion was prepared in 1930 by Robert Whitten. One of Mr. Whitten's proposals involved an elevated highway running from the North End of the City of Boston to the South End. The present Central Artery closely coincides with this route.

The Central Artery, completed in 1959 as an initial project in the development of the expressway system outlined in the 1948 Master Highway Plan, is unique in that it contains perhaps the widest vehicular tunnel in the world. An outstanding example for the entire country of excellent highway planning is the circumferential highway located about ten miles from the Boston Central Business District and designated as Route 128, which replaced an earlier route composed of local roads connecting and passing through the business centers of many of the cities and towns surrounding Boston. The completion of Route 128 provided, for the first time, an effective high-speed circumferential highway around the many congested districts of the Boston Metropolitan Area. The timing and location of this highway were ideal in making accessible the land necessary to satisfy the vigorous movement of people and industry in the post-war period.

Other completed parts of the expressway system serving the Boston Metropolitan Area consist of the Northeast Expressway to Route C-1 in Revere, the East Boston Expressway including a connection to Logan International Airport, the Southeast Expressway to Hingham, the Fall River Expressway from Fall River to Route 128, the Massachusetts Turnpike from the New York State line to Route 128, and the Northern Expressway to New Hampshire. The construction of the Massachusetts Turnpike Extension from Route 128 to downtown Boston has commenced and is expected to be completed by 1965.

A remarkable surge of extensive diversified industrial development is taking place within the area, particularly along Route 128. Industrial parks and regional and local shopping centers in the cities and towns within the area are receiving great impetus as a result of the encouragement of local governments and the efforts of federal and state governments to improve the highway system.

OTHER FORMS OF TRANSPORTATION

Excellent sea, air and rail transportation facilities are available to this area. Boston Harbor's deep-water channel leads directly to the open sea and is at least 200 miles closer to Europe than any other major east-coast seaport. The Logan International Airport is less than three miles from the Boston Central Business District. Three railroads link the Port of Boston with the entire New England Area. The New York, New Haven & Hartford Railroad serves the south, the Boston & Maine Railroad the north, and the New York Central Railroad the west. This railroad network began with the construction of a rail line from Quincy to Boston. Rail service to Providence, and connections to New York, to Maine, and to the west followed. These railroads set the pattern of radial

transportation lines outward from the "hub" at Boston.

Mass transit facilities began with the construction of an electric surface car line from Boston to Brookline, which started operating near the turn of the century. Through the years, these transit facilities were extended to the outlying points of Forest Hills, Everett, Harvard Square and Ashmont. Since World War II, extensions of rapid transit facilities have been made from Boston to Newton along the right-of-way of the Highland Branch of the Boston & Albany Railroad, and from Boston to Revere. However, much greater expansion is necessary to keep pace with the growth of the area. Extensions of mass transportation well into the suburban areas will attract many riders to the improved facilities, thus reducing vehicle travel desires. For instance, in the Greater Boston Economic Study Committee Report of 1960, it was asserted that the Highland Branch MTA service, as presently constituted, was furnishing the equivalent of one vehicular traffic lane during peak hours, that peak-period traffic congestion in Downtown Boston was reduced by about 7 per cent, and that 1300 parking spaces were freed for other use. In large metropolitan areas such as Boston, the solution of the transportation problem lies in developing a system of streets and expressways integrated with a mass transportation system including railroads, rapid transit, and buses.

INTEGRATION WITH MASS TRANSIT

The desirability of coordinating the design and location of the radial expressways with potential mass transit expansion was recognized in this Study, and expressway locations along existing railroad and mass transit rights-of-way were considered in detail. Where such a passenger facility occurred within a corridor of traffic desire, plans were developed to utilize either the right-of-way itself, or the area adjacent thereto for the location of the expressway. The location of the expressways and rapid transit or railroad facilities in the same corridor serves two functions. Primarily this arrangement will permit the road user to leave the expressway some distance from the core area, park in fringe parking lots located for the convenient transfer of commuters, and continue by rapid transit. Secondly, but equally important, this arrangement will utilize only one corridor for the transportation of goods and individuals and thereby permit more efficient use of adjoining land.

Southeast of Boston, railroad passenger service does not presently exist, and the rapid transit system extends only as far as Ashmont Station in Dorchester. The Southeast Expressway serves vehicular traffic to the South Shore, and is a typical example of the need to supplement expressway service with mass transportation service, in that this recently completed expressway facility is even now operating at capacity during peak hours.

Southwest of Boston, railroad passenger service is available, but rapid transit ends at the Forest Hills Station. The Southwest Expressway will complement these mass transportation facilities, but improvements to and the extension of the rapid transit in this area are also needed.

West of Boston, railroad passenger service is limited and the rapid transit Highland Branch Line extends as far as Newton. The Massachusetts Turnpike Extension, now under construction, will furnish Expressway service in this direction.

North of Boston, railroad passenger service extends in several directions, and these lines carry the greatest number of rail commuters in the Boston area. Rapid transit service is maintained to the north by the MTA to Revere, Everett, and Cambridge; however, these lines must be extended to provide adequate rapid transit service to the suburban communities, particularly if railroad commuter service is discontinued. The Northwest, Northern and Route 3 Expressways will provide vehicular traffic service for this northern area.

IMPROVEMENTS TO THE MASS TRANSIT SYSTEM

In 1959, the Massachusetts Legislature created the Mass Transportation Commission to study the extent and consequence of transportation problems, and in 1961 established a Special Legislative Recess Committee on Transportation to further this work. Previously in 1958, the Old Colony Area Transportation Commission was established to study the critical transportation problems resulting from the then current threat of rail service abandonment in the area (which is now a fact) and a report thereon was published in April 1959, recommending rapid transit service. The South Shore Transportation District was established by the Legislature in 1961 to provide rapid transit service between Boston and Braintree.

In November 1960, the Mass Transportation Commission undertook, with federal assistance, a long-range study of the entire metropolitan transportation problem, and on January 30, 1962, a report by the Joint Special Legislative Recess Committee was presented to the Legislature. A bill is currently before the Legislature providing for a Mass Transportation Commission program for planning and demonstration purposes. This program, among other related research matters, calls for traffic pattern studies, comprehensive origin and destination surveys, passenger attitude studies, rapid transit extension feasibility studies, and experiments on new types of equipment and related operational controls.

The extent of past, present, and contemplated studies by the several agencies and others having interest in or jurisdiction over mass transportation facilities, is impressive. The generalized types of solutions developed in these studies are demonstrable evidence of the Commonwealth's responsiveness to the serious nature of the problem. Principal recommendations from earlier reports included the following rapid transit extensions:

a. From the Ashmont MTA Station to Braintree or Brockton, with connections to Hingham and Whitman.
b. From Sullivan Square to Reading and Reading Highlands over Boston & Maine tracks, via Malden, Melrose, and Wakefield.

Other mass transportation extension projects of the rapid-transit type, previously recommended, are the following:

Forest Hills to Dedham-Needham
Kenmore Square to Brighton-Newtonville
Harvard Square to Waltham-Lexington
Boston to Winchester-Woburn
Revere to Lynn

Every effort should be made, by responsible agencies, for integration of present and contemplated studies of mass transportation with the recommendations of this Study.

NEEDS AND DESIRES

The heavy volumes of traffic using the Central Artery, Northeast Expressway, Southeast Expressway, Routes 2, 3, and 128, in addition to the traffic congestion on major arterial streets of the Metropolitan Area, are constant reminders to the commuter, businessman, and industrialist that the present partially-completed system for the transportation of people and commodities is grossly inadequate. Immediate relief of this congestion must be forthcoming to prevent utter traffic chaos and stagnation of the burgeoning business, industrial, institutional and residential development and redevelopment now in progress in the Metropolitan Area. No single factor will have a more profound effect on this development than completion of an adequately planned and properly designed Expressway System, integrated with complementing modes of transportation.

The existing expressways provide an excellent example of the effects an expressway has upon travel desires in, and development of, the urban and suburban areas through which it passes. The extensive changes that have taken place in Massachusetts since the inception of the expressway construction program are conclusive proof that an expressway promotes growth, development, and progress in the communities served. Many areas of Metropolitan Boston have not as yet realized the advantages of the proximity of a modern expressway. A lagging rate of growth and development in these communities, as well as considerable traffic congestion on their arterial streets, in most instances can be attributed to the incomplete Expressway System. The majority of these communities recognize the need, and desire the unique advantages afforded those communities served by the completed sections of the Expressway System.

The need for a modern highway system is supported by the knowledge that, as transportation services improve, business activity increases, accelerating development of the economic potential of the entire area, and resulting in a healthy, well-balanced family of communities. The desire is well established and the urgency for completion of this Expressway System is emphatically evident from the data and discussions contained in Traffic Analysis, Part III of this Report. Until the Expressway System is completed, a serious deficiency will exist in transportation facilities, thereby delaying progress, frustrating the desires, and abridging the potential of the Boston Metropolitan Area.

SECTION 2 – THE STUDY PROCEDURE

The preparation of this Study included several interdependent subordinate investigations and studies. Much of the work was undertaken concurrently, and some work spanned the entire duration of the Study. Detailed discussions of the procedures will be found in the relevant sections of this Study. The investigations and procedures, in their logical order, are as follows:

a. A complete detailed review was made of all previous reports and highway location data pertinent to the Boston Metropolitan Area. Consideration was given to all proposals and recommendations found therein, due regard being given to subsequent developments.

b. Location controls, comprising the terminals of existing expressways, topography, public and private institutions, general land use, railroads, major streets, existing street patterns, and feasible locations for interchange of traffic, were established. These controls, together with major traffic desires, essentially dictated the expressway locations.

c. Field reconnoissance of 25 miles of expressway corridors was undertaken. Particular attention was directed toward supplementing available records of the type, use and condition of dwellings, commercial and business establishments.

d. Available photogrammetric plans supplemented by aerial photographs, geological and subsurface data were acquired and studied. Street, utility, zoning, and proposed land-use plans were obtained from cities and towns for consideration of their effect on expressway location.

e. An original and unique mathematical model was devised for the purpose of forecasting traffic volumes in 65 communities of the Traffic Study Area. Because conventional methods of forecasting traffic were considered inadequate for the present purpose, extensive work was required to develop this model for engineering application, based on land-use and sociological data.

f. The study of the socio-economic effects of the Expressway System included 121 cities and towns in the region. Such factors as the overall economic base, shifting population, detailed employment trends, influence of zoning laws, and family incomes were all considered in this analysis. This Study included intense research work in development of satisfactory methods for the prediction of long-term functional benefits in advance of expressway construction.

g. Numerous alternative locations were considered for each expressway. Each alternative was studied in plan and profile, prepared in conformance with established design criteria.

h. Each alternative was evaluated with respect to right-of-way and construction costs, except in those cases where major disadvantages were so readily apparent that the location was discarded from further consideration. The right-of-way costs for each alternative involved establishment of the limits of construction on assessors' maps and determination of the street address, use, assessed value and fair market value for each parcel involved. Construction costs were tabulated under the major divisions of structures, earth work, pavement, utility relocations, and miscellaneous items and were developed by estimating the quantities of materials and applying unit prices which reflect current construction cost trends.

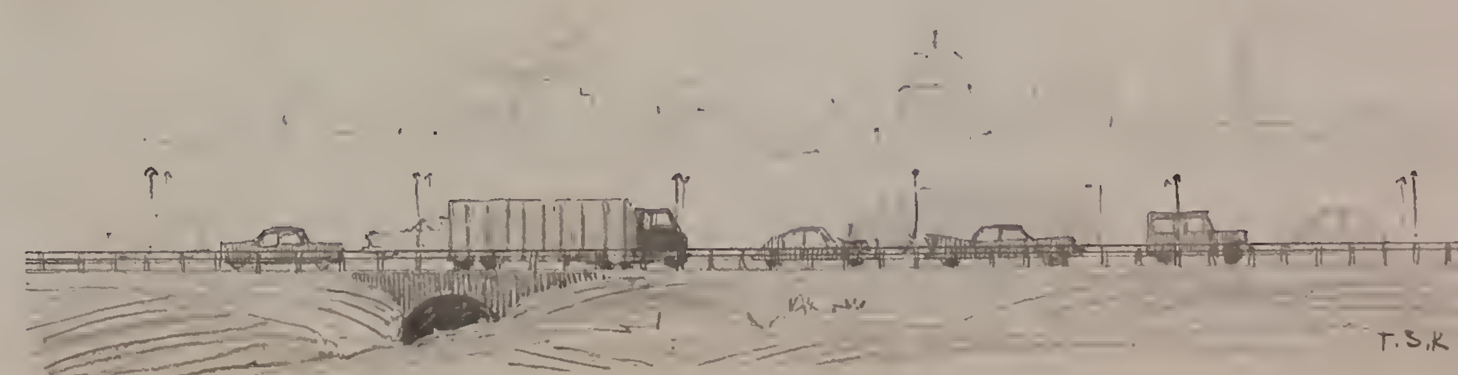
i. Each alternative was then evaluated on the basis of ability to serve the traffic desires, its long-term functional advantages, socio-economic effect, compatibility with the surrounding area, effect on long-range community planning, cost, and relative road-user benefits.

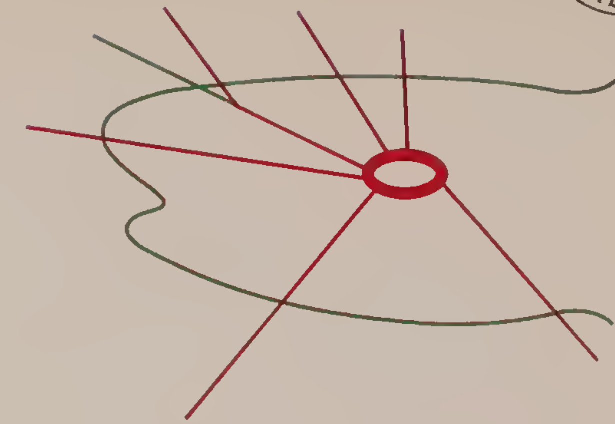
j. Meetings with representatives of the Massachusetts Department of Public Works and the Bureau of Public Roads were held frequently for the purpose of assuring maximum coordination.

k. In addition to these meetings, continuous liaison was maintained with officials and representatives of interested business and civic groups. Briefings on the alternative Inner Belt locations were conducted in order to effect coordination between Urban Renewal Programs and plans for the Expressway System. Representatives of religious, medical, and educational institutions, and civic and public agencies, attended meetings held to discuss possible Inner Belt locations.

l. An eleven-volume interim report was prepared and submitted in February 1960.

m. Public hearings were held in the spring of 1960 in Boston and Cambridge to provide the general public the opportunity to review, criticize and otherwise comment on the feasible alternative locations that resulted from the extensive highway, traffic and socio-economic studies. The records of these meetings were reviewed and evaluated, and wherever practicable, were reflected in the subsequent selection of the Recommended and Alternate Locations.





PART II

EXPRESSWAY LOCATION AND DESIGN CONSIDERATIONS

SECTION 1 – PHYSICAL LOCATION CONSIDERATIONS

METROPOLITAN BOSTON EXPRESSWAY SYSTEM

BACKGROUND AND DESCRIPTION

The basic design and layout for the Inner Belt and Expressway System included in the scope of this Study are based on the concept of a system of radial expressways leading into the vicinity of downtown Boston from the suburbs, and terminating at a circumferential Inner Belt Expressway, as shown in Exhibit L-1. This Inner Belt will function as an inter-connector between the several radials and as a collector-distributor for traffic having its destination or origin within the core area of Metropolitan Boston. This system of expressways was originally proposed in the 1948 Master Highway Plan. Sections of the expressway system proposed under the 1948 Plan have been constructed and are now in use. Other sections are presently being designed. Planning for the balance of the system, not yet constructed or under design, is the objective of this Study. The necessity for completing the system is strongly emphasized throughout this Report. In addition, the system must be augmented by supplementary facilities and improvements in order to handle effectively the traffic volumes predicted for 1975, the design year.

Sections of the expressway system of Metropolitan Boston have been designated as part of the National System of Interstate and Defense Highways, commonly called the Interstate System, as shown in Exhibit L-2. As such, they are an integral part of the nationwide network of limited-access highways that connect the principal metropolitan areas, cities and industrial centers, thereby contributing to the national defense. The Interstate System has been planned to interconnect the major population centers of the country with industry and defense establishments in such a manner as to insure that they are readily accessible by highways which offer a rapid, safe and dependable means of transportation. In the event of a national emergency, the Interstate Highway System will become one of the prime means

Exhibit L-1
METROPOLITAN EXPRESSWAY SYSTEM

Exhibit L-2

NATIONAL SYSTEM OF INTERSTATE AND DEFENSE HIGHWAYS

for the distribution of personnel and materiel of war.

Boston is the focal point of the Interstate System in New England, as shown in Exhibit L-3. This further accentuates the importance of the Inner Belt as an interconnector highway to distribute traffic from one interstate highway to another. This function is of prime importance in the shipment of raw materials to points of manufacture, manufactured goods to market, and the shipment of military supplies and defense materiel. All major defense establishments in Massachusetts are in close proximity to express highways, and the interconnection of these highways by the Inner Belt in Boston will provide a direct connection by way of limited-access expressways to these defense establishments.

The expressway system as planned for Metropolitan Boston is analogous to a wheel, with Route 128, the circumferential highway, around the outer fringes of Metropolitan Boston as the rim, the Inner Belt as the hub, and the radial expressways as spokes of the wheel. Six radial expressways were proposed in the 1948 Master Highway Plan as follows: Southeast, Southwest, Western, Northwest, Northern and Northeast Expressways. While changes and modifications have been made to the general plan as proposed by the Master Highway Plan, the basic concept of the radials remains the same. The essential function of the radials is to provide expressway service to the various sectors of the Boston Metropolitan Area to the extent that all the major concentrations of population will be served by expressways which connect the core city with Route 128. Expressway capacity for all vehicular traffic desires cannot economically be provided. The cost of such facilities would be prohibitive, the concept would be impractical, and furthermore would involve the use of virtually the entire core area for expressway land takings and parking facilities. Therefore, the optimum number of radial expressways would simply provide expressway service to the major desire areas on the basis of geographical coverage, rather than provide a sufficient number of radial ex-

Exhibit L-3
INTERSTATE SYSTEM OF NEW ENGLAND

pressways with capacity to satisfy the full desires of all vehicular traffic.

The six radial expressways will serve all the major population concentrations of the Boston Metropolitan Area, and furthermore will be so located that no point inside Route 128 will be more than three miles from an expressway, except in the Marblehead-Salem area. A lesser number of radials would not adequately serve the various population concentrations, and would result in an unbalance in the geographical coverage of each radial expressway, since the locations of the Northeast Expressway, Northern Expressway, the Massachusetts Turnpike, and the Southeast Expressway are now fixed. Additional radials would provide greater traffic capacity but at prohibitive cost as compared with alternative methods of transportation. With improvements made to the mass transit system and to the arterial streets and parkways, the six radial expressways have the potential capacity to serve satisfactorily the vehicular desires of the area.

COMPLETED PARTS OF THE EXPRESSWAY SYSTEM

The parts of the expressway system, as proposed by the 1948 Master Highway Plan, which have been completed and are now in use are as follows:

a. The Central Artery, officially named the John F. Fitzgerald Expressway, is a major segment completed in 1959. This expressway extends from an interchange with the Northeast Expressway, in the Boston and Maine Yards in Charlestown, through downtown Boston to a point in Roxbury at an interchange with the Southeast Expressway. The interchange with the Northeast Expressway is only partially completed and includes only that part of the interchange necessary to connect the two expressways. The interchange with the Southeast Expressway is fully completed and the Inner Belt extension toward Roxbury functions now solely as local access to Massachusetts Avenue.

b. The Southeast Expressway, from its interchange with the Central Artery to its interchange with Route 128 in Quincy and Braintree, and the extension of Route 128 to Hingham was completed in 1959.

c. The Northeast Expressway from its interchange with the Central Artery to its interchange with Route C-1 in Revere was completed in 1958; this section includes the Mystic River Bridge. The Northeast Expressway will be extended, as Interstate Route 95, in a new location to a connection with existing Interstate Route 95 in Danvers.

d. The Northern Expressway from its interchange with Route 128 to Salem Street in Medford was completed in 1961. The section of this expressway from Salem Street to Mystic Valley Parkway (Route 16) in Medford is presently under construction.

e. The East Boston Expressway, connecting the Sumner and Callahan Tunnels in East Boston with Logan Airport and McClellan Highway, was completed in 1951, and is programmed for extension as a limited-access facility to a connection with I-95 in Saugus.

f. The William F. Callahan Jr. Tunnel, the second tube of the Sumner Tunnel, connecting the Central Artery in Boston with the East Boston Expressway, was completed in 1961.

g. Route 128, the circumferential highway around the Boston Metropolitan Area, was begun in 1948 and is now completed from Gloucester on the North Shore to South Hingham on the South Shore. Its extension to a terminus at Hull is programmed for future construction. Parts of Route 128 which were originally constructed as a four-lane facility are now being widened.

The parts of the expressway system which have been or are being designed are as follows:

a. The Inner Belt from its interchange with the Northeast Expressway and the Central Artery, including the balance of that interchange, to a point just south of the Prison Point Bridge.

b. The extension of the Massachusetts Turnpike, functioning as the Western Expressway, from its present terminus at Route 128 in Weston to an interchange with the Central Artery at Broadway and Albany Streets.

c. Route 2 from Route 128 to Alewife Brook Parkway.

TERMINAL CONTROL POINTS

Of primary importance to the layout of the proposed expressways are the controls imposed by seven terminal control points resulting from existing construction and also from proposed construction for which the design has advanced beyond the preliminary planning stage. These seven terminal control points are indicated on Exhibit L-1 as follows:

☆ **INNER BELT** — The location of the existing terminus of the Central Artery at Massachusetts Avenue, in the Roxbury section of Boston, just south of the Boston City Hospital and just west of its interchange with the Southeast Expressway.

☆ **INNER BELT** — The location of the terminus of the segment of the Inner Belt which has been designed to a point just south of the Prison Point Bridge in the Boston and Maine Railroad Yard in Charlestown.

☆ **SOUTHWEST EXPRESSWAY** — The location of the proposed interchange with Route 128, determined by previous studies to be at a point just east of the Route 128 crossing of the Neponset River. The Southwest Expressway, including this interchange, is under design south of Route 128.

☆ **NORTHWEST EXPRESSWAY (ROUTE 2)** — The location of the junction of Route 2 and Alewife Brook Parkway.

☆ **ROUTE 3** — The location of the existing interchange of Route 3 with Route 128 in Burlington.

☆ **NORTHERN EXPRESSWAY** — The location of the Northern Expressway at the Mystic Valley Parkway, Route 16, in Medford now under construction.

☆ **MASSACHUSETTS TURNPIKE** — The location of the proposed extension of the Massachusetts Turnpike along the New York Central Railroad into the railroad's Allston yards.

Corridors of expressway locations were established in consideration of these terminal points. The locations of the existing terminal control points were predicated on planning which origi-

nated with the 1948 Master Highway Plan, and the corridors generally coincide with the expressway locations proposed by that Plan.

The Inner Belt must be located so that it will serve the central core area of Metropolitan Boston, which includes areas in Boston, Brookline, Cambridge, Somerville, Everett and Chelsea, as shown on Exhibit L-1. The Inner Belt must also be large enough in diameter to provide sufficient length for the direct interchanges with the radial expressways and an adequate number of local street interchanges. Additional radial expressways would necessitate a larger-diameter Inner Belt in order to provide sufficient length for additional interchanges. With a larger-diameter Inner Belt, the local interchange ramps could not be favorably located with relation to traffic desires, and the resulting longer length of travel over the local streets would result in greater local street congestion. Therefore, the optimum location of the Inner Belt is one that will adequately serve the traffic desires and provide for the direct-connection radial interchanges and the local street interchange ramps, with sufficient weaving distances between these points of access and egress.

The widths of the several study corridors varied with respect to traffic desires, topography, institutional and general land use, and practical locations of the interchanges of the several radial expressways with the Inner Belt. Each of the above factors has been considered in the study of alternative locations for the Inner Belt and Expressway System.

TOPOGRAPHIC CONTROLS

TERRAIN FEATURES

Major topographic features are important factors which must be considered in selection of expressway locations. The design criteria require gradual changes in direction, both horizontal and vertical, and therefore these features cannot be readily avoided. Topographic features in the Boston Metropolitan Area which have influenced the location of the expressways studied include, among others, the following:

RIVERS

Charles River, Mystic River and Neponset River.

HILLS

Highland Park, Parker Hill, Forest Hills, Bussey Hill, Brush Hill, Monterey Hill, Clarendon Hill, Little Blue Hill, Prospect Hill, Ten Hills, Turkey Hill, Follen Heights, Arlington Heights, Whipple Hill and Mt. Gilboa.

PONDS AND LAKES

Spy Pond, Upper and Lower Mystic Lakes and Fresh Pond.

The effect of topographic features on location is discussed in Part V for each of the separate expressways.

GEOLOGICAL DATA

The geology of the Boston Metropolitan Area involves surficial and bedrock formations. Surficial geology consists of the overburden atop the bedrock surface and varies in depth from zero at surface outcrops to approximately 250 feet below sea level in the study location areas. In these areas, the overburden materials existing from the buried rock floor upwards to ground surface consist generally of the following:

a. Glacial till or boulder clay, or both,
b. Glacial ground moraine of silt-to-gravel mixtures and boulders,
c. Fluvio-glacial outwash, stream-deposited inorganic silts, sands and gravels in varying mixtures,
d. Boston Blue Clay — a stratified, cohesive, sedimentary deposit of clays and silts of glacial origin, believed to have been deposited in a temporary glacial lake,
e. Beach sands and other sands and gravels,
f. Marine silt, muck, and peat,
g. Filled land.

The distribution of these sediments in both horizontal and vertical directions is of considerable complexity. The till, boulder clay, moraines and granular outwash formations and the Boston Blue Clay deposit are of glacial origin. Some were deposited directly by ice or in close proximity to the ice, and therefore are generally heterogeneous unstratified mixtures of clay-to-gravel sizes and boulders, a mixture called glacial till or hardpan. They are usually cemented and are very dense. Where the content of clay sizes is high, the till formation is often called boulder clay. The ground moraine is of somewhat similar origin. It is well-compacted but contains fewer fines and relatively more sand constituents and is generally uncemented. The outwash and morainal sands and gravel are well-sorted and stratified and are completely cohesionless. They usually occur in a relatively loose state of compaction. Beds of silt and fine sand frequently occur interstratified with the coarser sand and gravels. Beach sands and other sands and gravels occur in the coastal areas. The beach sands are derived from wave erosion and re-working of glacial till, forming the backbone of the many peninsulas defining the coast line. Due to the relatively large areas of surface layers of filled land, the extent of marine silt, muck, and peat is not clearly indicated. Much of the section adjoining the Charles River Basin has been reclaimed from inundated marsh land.

The Boston area itself is dominated geologically by the Boston Basin, once the mouth of a pre-glacial stream which is now the Merrimac River. It is a deep, roughly saucer-shaped depression which has been filled with a thick bed of clay overlain in many places by a shallow layer of relatively dense granular material. This crust, however, is typically erratic and unpredictable. An important characteristic of the clay deposit is that its upper portion has been desiccated and oxidized, probably by a drawdown of the water table and atmospheric exposure during some time in the geologic past. This portion has a distinctive yellow-brown color, and is known locally as yellow clay. As a consequence of the drawdown the clay deposit on the surface is very stiff due to pre-consolidation, becoming gradually softer with increasing depth. The deeper clays have a blue-gray or olive-green color and have been described in soil-boring reports as being soft and plastic.

Bedrock geology includes the various deposits forming the bedrock floor. These are highly consolidated by the previous effects of pressure or organic cementation or both. The bedrock geology in the Boston Basin consists of the following major formations:

a. Cambridge Argillite

Cambridge Argillite is a formation consisting chiefly of rock of generally fine-grained argillaceous character that has been called shale and sand shale, argillite, and slate. The typical Cambridge slate is dark bluish-gray or brownish-gray, rather fine-grained, and composed chiefly of argillaceous material. Some parts of it are well-stratified and thin-bedded; other parts are rather massive. Most of it easily splits parallel to the bedding, and nearly everywhere it has developed a fissility across the bedding, but only rarely is the secondary structure dominant, and practically nowhere in the Basin is the rock a true slate.

b. Roxbury Conglomerate

The Roxbury Conglomerate is a highly variable formation, for in addition to the dominant conglomerate, it contains shale, slate, argillite, sandstone, quartzite, altered basalt and volcanic tuff. The conglomerate phase contains pebbles and boulders varying from an inch to a foot in diameter. The conglomerate is often exceedingly massive and it is frequently difficult to find any evidence of stratification.

c. Mattapan Volcanics and Basement Complex

The Mattapan Volcanics and Basement Complex consist of volcanic rocks of the carboniferous period, partly intrusive or extrusive or both, and partly sedimentary. The former are broadly classed as felsites and granite porphyry and melaphyre. The sedimentary rocks are predominantly tuffs, breccias and mud flows, deposited in water courses and occasionally interbedded with conglomerates, sandstones and slates, also of volcanic origin. The conglomerate and sandstone lenses of this formation are similar to the coarser Roxbury Conglomerate formation described above.

Outside of the Boston Basin the subsurface conditions are extremely variable and are discussed in Part V with reference to the expressway locations. Subsurface information collected for these studies are based on published data, particularly "Boring Data From Greater Boston," by the Boston Society of Civil Engineers, and on unpublished information from a variety of sources, primarily local boring contractors. This subsurface information available was adequate for basic design considerations.

LAND-USE CONTROLS

Integrated areas of land use have a greater effect on expressway location than any other single factor. Their effectiveness as community assets would be adversely affected if the location of the expressway were such as to interfere with the integrity of integrated areas of land use. The purpose and function of the expressway is to provide increased vehicular accessibility for adjacent areas, and thereby to allow development of land to its highest potential. This purpose would be defeated if, in the process, the expressway were located so as to reduce the desirability of previously-developed large land-use complexes.

Examples of land-use complexes which affect the location of the several expressways are parks and recreational areas, housing developments, hospitals, churches, educational institutions, large industrial, business, or commercial developments, established neighborhoods, and land in general which has been developed to its maximum potential. The effect of land-use complexes on location is discussed in detail for each of the separate expressways in Part V.

PUBLIC AND PRIVATE UTILITIES

In the large, densely populated Boston Metropolitan Area there are many public and private utilities which are of vital importance. These utilities consist of sewers, storm drains, water mains, gas mains, telephone and electrical distribution lines, together with rapid transit and railroad lines. These facilities are costly to relocate and therefore influence the location of expressways. The locations of several of the major intercepting sewers of the Metropolitan District Commission and the City of Boston had a particularly important effect on the alternative expressway locations.

SECTION 2 – DESIGN CONSIDERATIONS

BASIC DESIGN CRITERIA

A properly-designed urban expressway system comprises optimum features of traffic service, operational efficiency, economy, aesthetics and safety. The design features adopted are consistent with the policies of the Federal Bureau of Public Roads and the Massachusetts Department of Public Works. *A Policy on Arterial Highways in Urban Areas* of the American Association of State Highway Officials, and *Manual of Instructions for Preparation of Plans* of the Massachusetts Department of Public Works have been used as guides in the preparation of the basic design of the expressways. The basic design criteria of the Inner Belt and Expressway System have been prepared in accordance with these policies and are shown in Table L-1. Controlling design speeds are as follows:

DESIGN SPEED 50 mph — Inner Belt, radial expressways and direct connections, except segments of the Southwest Expressway and Route 3 immediately inside of Route 128, where a transition section permits a change in speed from the 70-mile-per-hour design speed outside Route 128 to a 50-mile-per-hour design speed inside Route 128.

DESIGN SPEED 40 mph — Direct connections for the interchange of the Inner Belt with the Massachusetts Turnpike, where toll booths preclude the necessity of a higher design speed.

DESIGN SPEED 25 mph — Local access ramps.

OTHER DESIGN FEATURES

All the expressways included within the scope of this Study have been designed as controlled-access facilities, permitting access and egress at ramps only. The maximum number of travel lanes recommended for the Inner Belt and Expressway System is limited by economic and lane-efficiency factors. Eight travel lanes are generally recommended for each expressway with the exception that four lanes are recommended for Route 3 between Route 128 and its junction with Route 2. The number of travel lanes recommended and the design volume of traffic for each segment are shown on the Basic Design Exhibits for each expressway.

Recommended typical expressway cross-sections, Exhibits L-4 and L-5, show the basic design elements and serve as the basis for estimating the costs of construction and acquisition of the right-of-way. It is recommended that 12-foot travel lanes, 10-foot paved right shoulders and 4-foot paved left shoulders be provided throughout the Expressway System. The use of a 10-foot paved right shoulder on long bridges, viaducts and depressed sections is an exception to the policies governing the designs presented in this Study. However, experience in the operation of urban expressways carrying high traffic volumes has demonstrated the necessity of making this exception. Breakdowns which occur on the expressway at points where the paved shoulder has been omitted are responsible for materially reducing the expressway capacity and thereby causing serious traffic congestion. The basic designs and related cost data have been prepared on the basis of the use of 10-foot and 4-foot shoulders throughout the system.

All ramps for local street interchanges are 22 feet in width to provide one travel lane in addition to space which would allow the storage of vehicles during peak use, provision to pass breakdowns, and for storage of snow under heavy snowfall conditions.

The controlling vertical clearance for all expressways included in this Study is 14 feet 3 inches. However, subsequent to the adoption of this value, the Southwest Expressway was designated as the route into the port of Boston which must provide 16 feet of vertical clearance to meet military and defense requirements. The 16-foot clearance could be provided at time of final design for the Southwest Expressway and would result in a slight increase in the construction cost.

In urban areas essentially continuous frontage or collector-distributor roads, with a minimum of two travel lanes and a shoulder in each direction, are recommended as an integral part of the expressway system. The function of these roadways will be:

a. To act as a feeder or collector-distributor system for the expressway itself, by augmenting the existing street system in the collection and distribution of traffic to and from the ramps of the expressway. This function of the frontage road system alone is of sufficient importance to justify their construction since in many instances traffic volumes to be handled by ramps exceed the traffic-handling capacity of adjoining existing streets without such frontage roads.

b. To preserve the continuity of local streets cut off by the expressway, thus reducing the number of bridges otherwise necessary to maintain continuity, and to provide access to properties which otherwise would be denied access due to the expressway location.

TABLE L-1
DESIGN CRITERIA

Item	DESIGN SPEED 50 mph	40 mph	25 mph
Horizontal Curves:			
Radii*:			
Desirable, ft	3,300	—	—
Desirable Minimum, ft	1,000	—	—
Absolute Minimum, ft	830	500	150
Superelevation, Max., ft/ft	.06	.06	.06
Grades:			
Desirable Maximum	3.0%	3.0%	4.0%
Absolute Maximum	5.0%	5.0%	6.0%
Desirable Minimum	0.5%	0.5%	0.5%
Absolute Minimum	0.4%	0.4%	0.4%
Vertical Curves:			
Curvature, K:			
Crests:			
Minimum	80	50	30
Maximum	143	143	143
Sags:			
Minimum	100	50	40

*Three-centered compound curves for radii less than 3,300 feet.

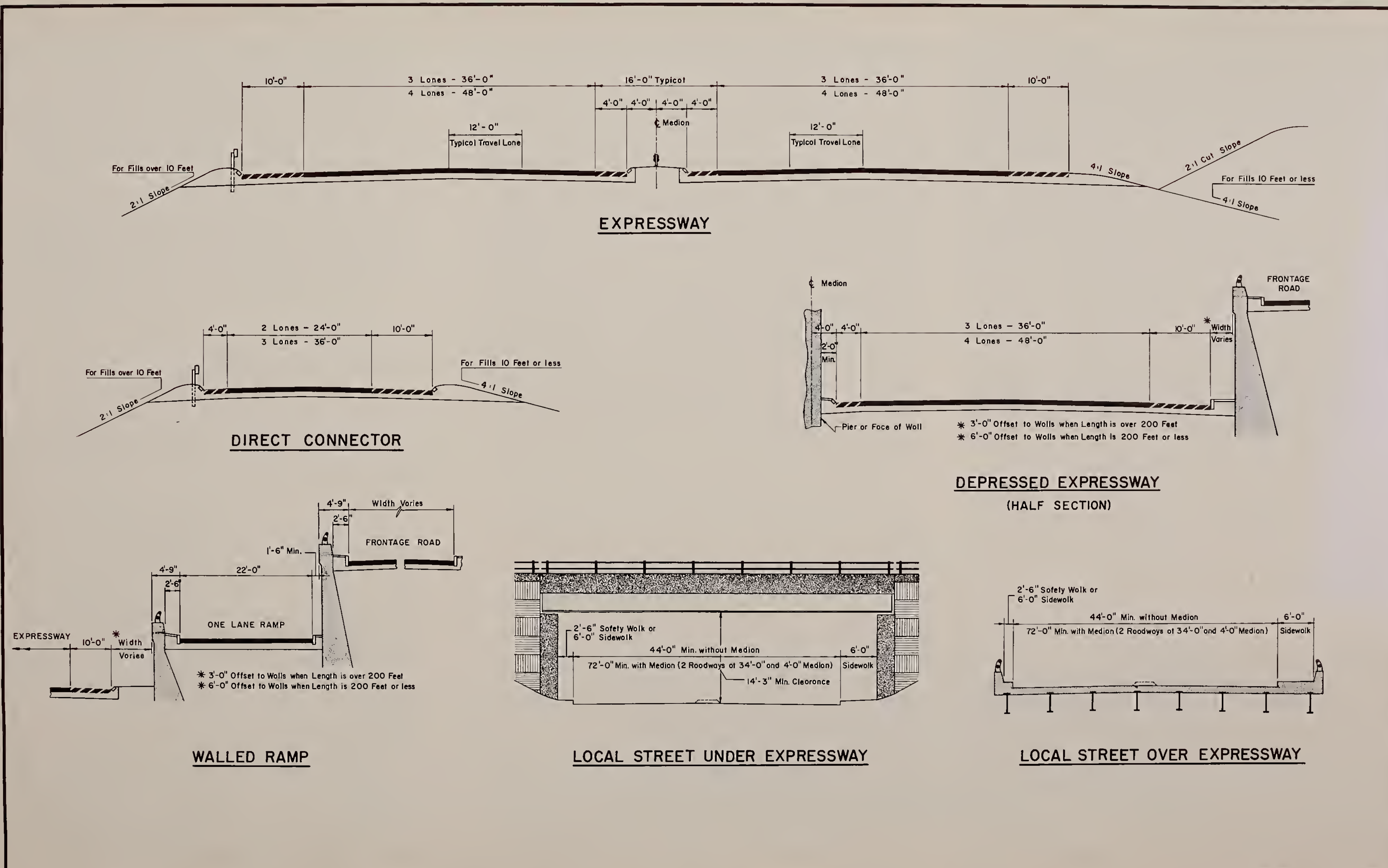


Exhibit L-4

TYPICAL CROSS SECTIONS

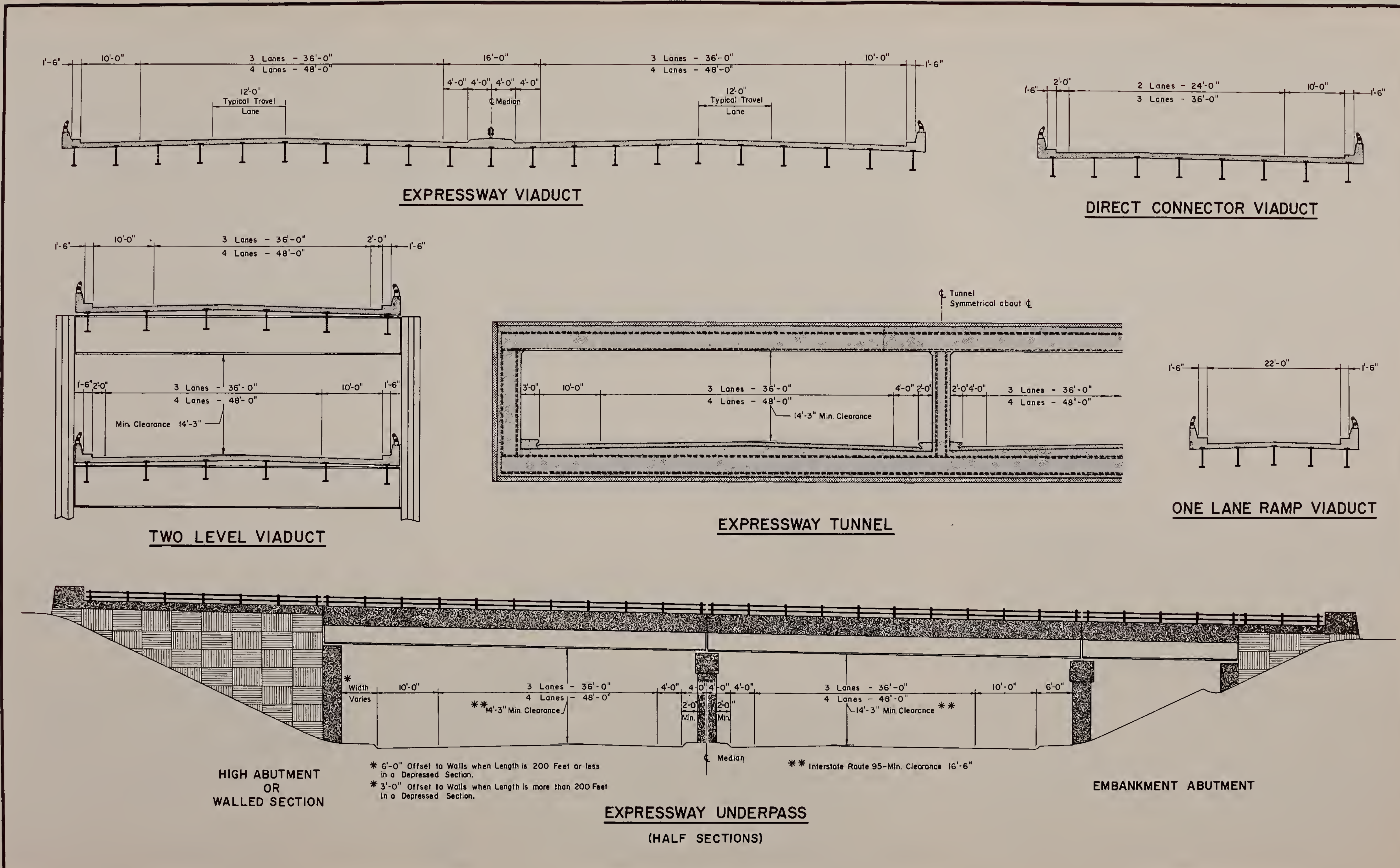


Exhibit L-5
TYPICAL CROSS SECTIONS

c. To improve the expressway operation by providing additional capacity for traffic consisting of relatively shorter local trips than those assigned to the expressway.

Lighting is recommended as a necessary safety measure for the entire Expressway System, including frontage roads, because of the high volumes of traffic utilizing the facility and the frequency of the location of interchanges. Landscaping of the expressway system is an important part of the initial expressway construction, and is considered as a functional as well as aesthetic factor.

TRAFFIC CONSIDERATIONS

EXPRESSWAY LOCATION

The 1975 travel desires are based upon the completion of the transportation system and the anticipated economic growth of the Boston Metropolitan Area. To satisfy completely the future travel desires solely with the construction of additional expressways would result in a prohibitively expensive and impractical system. The mass transportation system must be improved by the extension of present rapid transit lines and the addition of other lines, and improvements must be made to existing arterial streets in order to satisfy the transportation demands of the anticipated growth of the area. Therefore, the traffic capacity provided by the expressways represents only a partial fulfillment of all 1975 travel desires.

The corridor of possible location of each of the expressways was established by the terminal control points which were set by previous study or existing construction. Since the forecasted travel desire in the corridor exceeds the expressway capacity, the assigned traffic will reach capacity regardless of the location of the expressway, provided that:

a. The locations within the corridor remain in areas of similar land-use intensity.

b. The locations do not vary sufficiently to overlap areas served by other expressways.

c. The locations have interchanges which provide comparable local traffic service.

The 1975 traffic assignments made to the various expressway networks verify the minimal effect of location on traffic volumes.

EXPRESSWAY LOCATION WITH RESPECT TO MAJOR STREETS AND STREET PATTERNS

The expressway must be accessible via the existing street system and must be so located that maximum use may be made of major arterial streets in supplying and absorbing the expressway traffic. Even with provision for collector-distributor roads to distribute the traffic, congestion would be inevitable if the traffic could not readily be dispersed to major streets, since a single expressway ramp is capable of handling a greater volume of traffic than can be supplied or absorbed by most streets. Therefore, the expressway location with respect to major arterial streets, parkways, and the local street pattern, is an important consideration in determining its functional effectiveness.

FREQUENCY AND RELATIVE LOCATION OF LOCAL RAMP SERVICE

The number of ramps necessary for local street interchanges and their relative location was a major consideration in the analysis of alternative Inner Belt locations. There must be a sufficient number of ramps so that the traffic desire does not exceed the ramp capacity, and the ramp location must be in reasonable proximity to the origin or destination of its assigned traffic. In addition, the location of the direct connections to the radial expressways further restricted the number and location of the local interchanges, due to the necessity of providing proper weaving distances to maintain efficient operation of the expressway system.

Sufficient information was obtained from the traffic assignment program for analysis of each ramp location and to make adjustments to meet the traffic desires. These adjustments were made consistent with factors which influence ramp location, particularly the ability of the local streets adjacent to the expressway to accommodate the assigned ramp traffic, the provision of adequate weaving distances for operation, and the comparative costs of a ramp in different locations.

EFFECTS OF EXPRESSWAY LOCATION

Urban expressway construction will inevitably have immediate and long-term effects upon the structure of an area and the people who inhabit the area. Experience has shown that a location which is economically sound and otherwise highly advantageous to expressway users may temporarily disrupt a community and its habitants unless proper precautions are taken to minimize such disruption. The evaluation of all conditions relating to and resulting from proposed construction is absolutely necessary to permit the selection of that expressway location with maximum potential for the community's long-range growth and development, and maximum benefits to the road-user consistent with the minimum adverse effect upon the communities involved. The road-user and non-road-user benefits of each expressway location must be weighed against its economic costs, and therefore the economic analysis involved consideration of physical effects, benefits to highway users, and construction, land acquisition, and maintenance costs for alternative locations.

The effects of the expressways studied were divided into two categories: physical effects and functional effects. The physical effects comprise the short-term effects of the highways as physical entities newly introduced into an existing urban environment; the functional effects consist of the long-term benefits of the highways upon the growth and development of the communities in the Socio-Economic Study Area, with particular emphasis on those communities in which the Inner Belt and Expressway System will be constructed.

The physical and functional effects influence individuals and groups to highly variable degrees. These groups consist of local governments, residents, community groups, commercial and business interests, manufacturers, public services and others. The nature of the effects upon each group in each community was carefully analyzed. Since the objectives of the Socio-Economic Study involved advance determination of adverse short-term physical effects, together with forecasts of beneficial long-term functional effects on community growth and development, it was inherent to the Study that equal consideration be given to each group in order to assure maximum future benefits for all. In the final analysis, emphasis was given to the opportunity for urban growth and development of each of the cities and towns affected by the expressway system. It was considered that this approach was most beneficial to the long-range interests of the general public.

The physical effects had an important bearing on the selection of the Recommended and Alternate Locations from among the numerous alternatives studied. Since construction of urban expressways requires land already in use for other purposes, the physical effects are primarily those relating to the displacement of existing land-users. The primary aim was to establish a framework around which the communities could plan a pattern of development which would capitalize on the improvement in transportation.

The functional effects are similar for each expressway, because all locations were in relatively narrow corridors with no appreciable difference in expressway travel times among the various locations studied.

Expressway construction of the magnitude contemplated in this Study will produce fundamental changes in the structure of the Boston Metropolitan Area. Changed time relationships among the cities and towns in the Study Area will result in concomitant changes in the location of future residential, commercial and industrial developments. The Socio-Economic Analysis predicted the pattern of development for 1975, and then evaluated the effects of this development upon the various groups in the community.

ROAD-USER BENEFITS

The road-user benefit analysis is a method for evaluating the economic justification of new expressways. It provides a comparison of the relative value to the road-user of travel on an expressway as compared with travel on existing streets. The road-user benefit ratio is expressed as the ratio of annual road-user benefits obtained through the use of the expressway as related to the total annual costs of the expressway. This ratio has been computed for the Recommended and Alternate Locations for each of the expressways, and the results are evaluated in Part V of this Study.

The essential factors in the determination of a Road-User Benefit Ratio are outlined as follows:[1]*

a. Costs of construction and right-of-way for the expressway;
b. Costs of maintenance and operation of expressways and their appurtenances;
c. Direct benefits to road users in the form of reduced vehicle operating costs and saving in time by use of the expressway;
d. Benefits to road users in the form of increased comfort and convenience; and
e. Benefits to road users in the form of overall accident reduction.

The formula for determining the Road-User Benefit Ratio follows:

$$\text{Benefit Ratio} = \frac{\text{Annual Road-User Benefits}}{\text{Annual Costs}}$$

Where

Annual Road-User Benefits equal Annual Road-User Cost on Existing Streets minus Annual Road-User Costs via Expressway; Annual Costs equal Annual Project Cost plus Annual Maintenance Cost for Expressway minus Annual Maintenance Cost for Existing Streets.

The annual road-user costs for the expressways and existing streets were determined by multiplying the following items: the traffic assigned thereto for 1975, the appropriate vehicle operating costs in cents per vehicle-mile, the length in miles of travel on either the expressway or existing street, and the days per year.

The annual project cost consists of the amortized annual costs of construction and right-of-way. Demolition costs and engineering and contingency costs were included as part of the construction costs.

*References will be found in the Appendix.

In order to obtain amortized annual costs of construction and right-of-way and maintenance costs, Items a and b above, the following were assumed:

Prevailing Interest Rate:	5%
Average Life of Right-of-Way:	60 years
Average Life of Structure, Drainage and Pavement:	40 years
Annual Maintenance Costs of Expressways:	$20,000/mile
Annual Maintenance Costs of Existing Streets:	$ 3,500/mile

The cost units pertaining to Items (c), (d), and (e) were derived from two recent studies and an AASHO Report[1]. In the determination of road-user benefits, two factors are:

a. The average speed over the expressway and on the local street path serving the same origin and destination.

b. The total vehicle operating cost per mile at the average speeds for expressway and street travel.

From a travel-time study by Bone and Memmott[2], pertinent data as to average speed over existing expressways and comparable local streets were selected for use in this Study as shown in Table L-II. A study by Hoch[3] presented detailed costs per vehicle-mile related to average speeds, as shown in Table L-II,

TABLE L-II
VEHICLE COSTS PER MILE AT AVERAGE SPEEDS

Expressway Speed (Miles per hour)	Total Vehicle Cost (Cents Per Vehicle Mile)
30	8.4
40	6.7
45	6.5
Local Street Speed (Miles per Hour)	
14	17.0
20	12.3
25	10.0

which costs include time costs, operating costs, and accident costs. The cost of stops was also reflected by the average speed; fuel consumption while idling was based on an estimate of 0.35 minutes per stop.

The completion of the proposed expressway system for the Boston Metropolitan Area will be justified by direct benefits to the motorist through lower vehicle operating costs, lower accident rate, substantial time savings, and increased comfort and convenience.

AESTHETIC CONSIDERATIONS

Expressways were located with special consideration of the land-use patterns of the area to minimize disruption to the urban structure of the community and, where practicable, to provide an effective barrier between existing and proposed industrial and residential areas. Where practicable, the expressway section has been depressed to remove it from sight and reduce the noise level in surrounding areas. Construction cost estimates of expressway construction include landscaping and related work. Landscaping would be in harmony with the character of the highway development and should be included in the initial construction design. Effective roadside landscaping will benefit both the road-user and the roadside developments adjacent to the expressways. An effectively landscaped expressway will aid in absorbing vehicular noises, screen the sight of moving traffic, and reduce headlight glare.

SECTION 4 – PROJECT COST CONSIDERATIONS

GENERAL

The project cost considerations comprise the construction costs, right-of-way costs, and other costs. Construction costs include all costs for the construction of the Expressway System and appurtenant work. Right-of-way costs include the costs for all land acquisition required to construct the Expressway System and appurtenant work. Other costs include the costs for demolition or clearance of the right-of-way, costs for engineering design and supervision, and a contingency allowance for project budget purposes.

CONSTRUCTION COSTS

The preliminary estimates of cost of construction have been prepared for the Recommended and Alternate Locations shown on the Basic Design Exhibits presented in Part V. Preliminary plans were developed at a large scale; the quantities of construction materials were estimated on the basis of the type of construction indicated on these plans and profiles, and unit prices were applied to these quantities. The unit prices used for the various construction materials reflect current trends in urban highway construction costs.

The total construction costs for the Expressway System include all local-service ramps, frontage roads, and surface street improvements necessary for expressway operation to the extent shown on the Basic Design Exhibits. In addition, all miscellaneous items which affect construction costs are included. These items comprise utility relocation, lighting, signing, alteration of facilities such as rapid transit lines and railroads and maintenance of traffic thereon, railroad force accounts, temporary facilities for maintenance of street traffic, pumping facilities for sections depressed below existing gravity drains, and other appurtenant categories of work. All costs have been prepared based on construction in conformity with the design criteria presented herein. The construction costs are sub-divided geographically, for each expressway, and into major categories as follows:

STRUCTURES: Viaduct, bridges, retaining walls, waterproofed depressed sections, culverts, tunnels, and appurtenant work.

EARTHWORK: Rock, bridge and roadway excavation, and ordinary and gravel borrow.

PAVEMENT: Sub-base, surfacing, roadway drainage, and loaming and seeding.

UTILITY RELOCATION: Relocation and alteration of all public utilities and surface drains.

MISCELLANEOUS: All curbing, guard rails, lighting, signs, landscaping, and special problems such as alterations to rapid transit facilities and railroads.

The estimates for the Recommended and Alternate Locations of the Inner Belt include the costs of the direct-connection interchanges with the radial expressways. The limits of the estimates for the Inner Belt are the end of the permanent construction of the Central Artery, approximately 500 feet east of Massachusetts Avenue, and the end of the previously-designed section of the Inner Belt, in the Boston and Maine Railroad yard at Prison Point Bridge in Charlestown. The estimates include costs for the connections to the Massachusetts Turnpike in the Allston yard of the New York Central Railroad. The limits of the estimates for the various radial expressways are as shown on the Basic Design Exhibits.

RIGHT-OF-WAY COSTS

The preliminary estimates of the cost of right-of-way acquisition include the cost for acquisition of all land necessary to construct the facilities shown on each of the Basic Design Exhibits, including the land necessary to construct the ramps, frontage roads, and alteration of existing streets at the local interchanges. The estimates also include the cost for such easements as may be necessary to construct the expressway and its appurtenant structures, and an allowance for severance damages in the case of partial takings. Wherever more than half a parcel was required, or wherever the remaining area of a parcel, regardless of its proportion to the whole, was left without a means of access to a public way, the value of the entire parcel was included in the estimate. Where a usable part of commercial structures of high value remained outside the taking line established, that part was not included in the estimate. An allowance was made for that part of the building taken, plus severance damages to compensate for the cost of alterations to the remaining part and for its diminished value.

In order to arrive at an estimate of right-of-way costs, a limit of construction was first established on basic design plans for each expressway location, on the basis of recommended clearances between new construction and existing structures, with due regard for the conditions under which partial takings might be made. The limit of construction was then transferred to assessors' maps and adjusted, as necessary, to form a taking line to provide the proper clearances and space for construction purposes. When the taking lines had been established, city directories, Sanborn maps, and assessors' records were used to obtain, for each parcel, information on its street address, assessors' plan number, block and lot number, parcel use, type of structure, number of dwelling units, tax status, area, assessed values of land and buildings, and total assessed value. To the assessed value, a ratio was then applied to arrive at the "fair market value."

Fair market value may be defined as the most probable price at which a well-informed buyer would be willing to purchase and at which a well-informed seller would be willing to sell. In order to establish such values for the right-of-way estimates, and to obtain an index of property values along the several routes under consideration, copies of the *Banker and Tradesman*, a weekly real-estate journal, were examined. This publication lists real-estate transfers in each municipality in Massachusetts by street address, and it indicates the value of the tax stamps used for the transaction. The sale price of the property was computed at a rate of $1.10 in tax per thousand dollars of transaction. A sample of price variations was obtained by listing the sale prices and correlating these with the field survey reports to determine the use, size, type of construction, and condition of each sample. A field check of values was made to eliminate any discrepancies in this method of determining an indication of value. The results were then used to develop ratios of assessed value to fair market value for the City of Boston and the other cities and towns, as presented below.

TABLE L-III
RATIOS OF FAIR MARKET VALUE TO ASSESSMENT CITY OF BOSTON

Type of Use	Range of Ratios		
Single Family	1.00	to	2.95
Multi-Family	0.706	to	2.59
Apartment	0.556	to	3.08
Mercantile	0.401	to	2.24
Vacant Land	0.692	to	2.94

CITY OF BOSTON

The extreme complexity of property value patterns within the corporate limits of the City of Boston, as compared with the usual pattern of single- and two-family dwellings predominating in surrounding communities, required a method of approach for the estimate of fair market value different from the procedure adopted in the other cities and towns.

Some 528 sales listed in *Banker and Tradesman* between August 2, 1958 and January 2, 1960 were compared with assessed valuation, and ratios of fair market to assessed value were determined. A close examination of these data disclosed that there was an unusually wide variation in different sections of the City of Boston, and within certain districts a substantial differential existed among various classifications of properties. The expressway areas in Boston therefore were divided into nine sections, consisting of five along the Inner Belt and four along the Southwest Expressway. Each section contained five classifications of property, each having a separate Fair Market Value Ratio. These classifications are Single-Family, Multi-Family (2 to 6 families), Apartments (7 or more families), Vacant Land, and Mercantile. A range of the values obtained for the Fair Market Value Ratio for each classification of property in Boston appears in Table L-III.

The City of Boston has undertaken condemnation of certain unsafe structures together with demolition and clearing of land. When an owner refuses to comply with demolition and clearing orders, title to the parcel is acquired by the City of Boston through appropriate legal procedures, and the City then effects the required demolition and clearing. Since the value of such land is usually low, it may be utilized to economical advantage for expressway purposes. In certain sections of Boston within the area of expressway location, such cleared land comprises up to 10% of the total area required for the expressway.

OTHER CITIES AND TOWNS

Approximately 1,400 sales listed in *Banker and Tradesman* between August 2, 1958 and January 2, 1960, were used to determine the ratios of assessed to fair market value for Brookline, Cambridge, Somerville, Arlington, Lexington, Belmont, Medford, Winchester and Woburn. The structures and parcels included in the right-of-way cost estimates were divided into the same five categories used for Boston. In Cambridge, Somerville and Brookline, there were four times as many single- and multi-family structures compared to other types of structures. The lack of sufficient sales of all the types of structures to obtain a realistic ratio in each city and town within the area of influence of the expressways necessitated the use of a single ratio for each of these cities and towns.

In Arlington, Belmont, Lexington, Winchester and Woburn, the expressways pass essentially through recently-developed housing areas, and the sales reported in *Banker and Tradesman* involve predominantly single-family homes sold by developers in these areas. A lack of sufficient sales of other types of properties, and the predominance of single- or multi-family structures taken, thus led to the development of a single ratio for each of these towns. In Canton and Milton, only vacant land would be acquired and most of the land required for the Southwest Expressway is in M.D.C. Reservations. In these cases, assessed valuations were doubled to estimate a fair market value without recourse to investigations into recent real estate sales. In Burlington, all land necessary for the construction of the Route 3 Expressway has been acquired by the Commonwealth. The Fair Market Value Ratios used in obtaining fair market value from assessed valuations in these communities are shown in Table L-IV.

OTHER COSTS

DEMOLITION COSTS

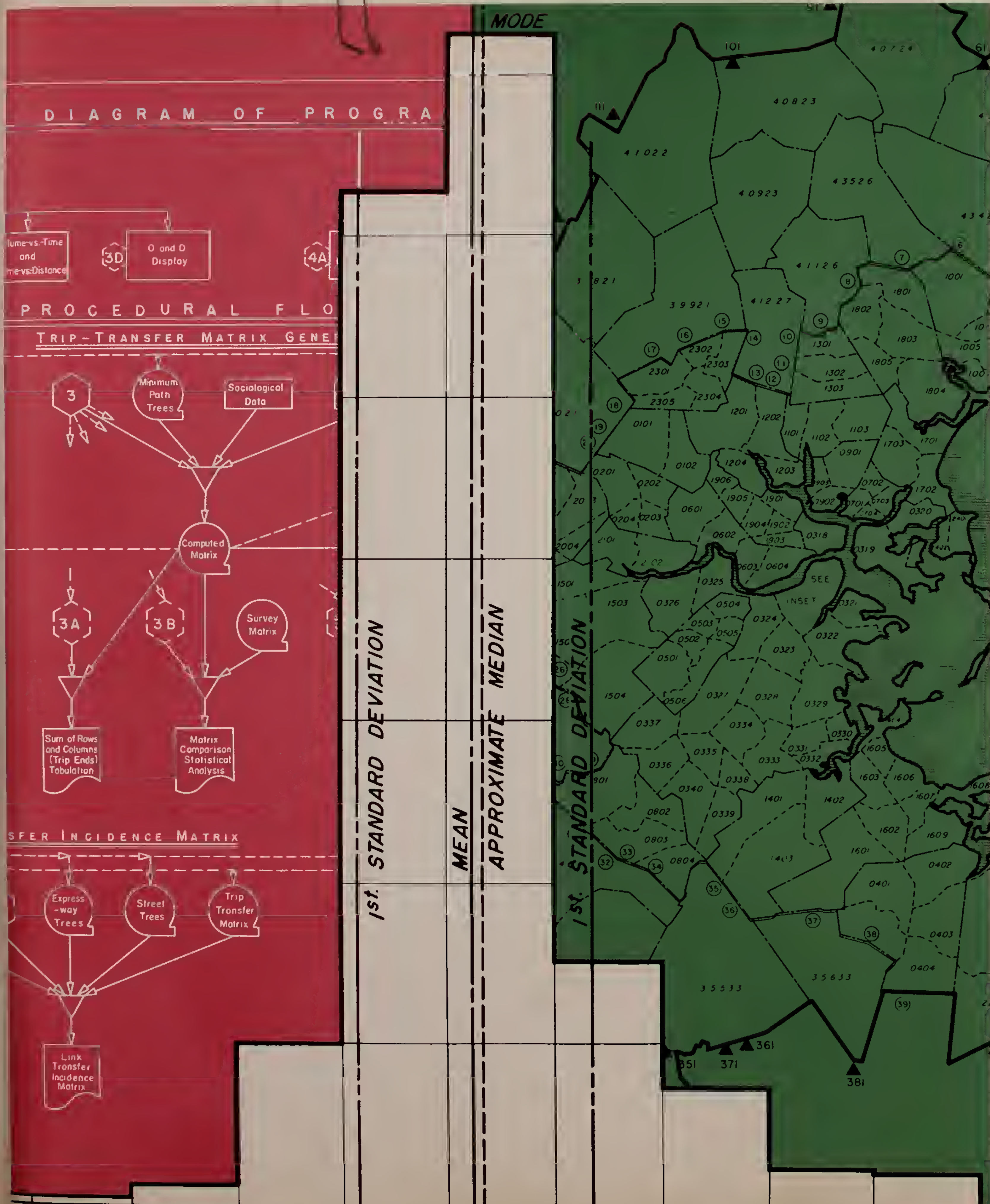
The cost of demolition was estimated on the basis of an evaluation of the type of construction of each structure.

ENGINEERING COSTS AND CONTINGENCIES

The costs of engineering design, supervision of construction, and contingencies were based on an allowance of 10% for engineering and 5% for contingencies, and were computed on the basis of 15% of the total cost of construction and demolition.

TABLE L-IV
RATIOS OF FAIR MARKET VALUE TO ASSESSMENT CITIES AND TOWNS OTHER THAN BOSTON

City or Town	Ratio
Arlington	2.70
Belmont	2.78
Boston (Charlestown)	1.45
Brookline	1.73
Burlington	Not Required
Cambridge	1.76
Canton	2.00
Lexington	2.50
Medford	2.02
Milton	2.00
Somerville	1.82
Winchester	2.56
Woburn	2.18



PART III

TRAFFIC ANALYSIS

SECTION 1 – INTRODUCTION

PRIOR STUDIES

Numerous published and unpublished traffic and highway planning reports were reviewed early in the present study. Of primary interest are three studies which span a period of thirty years and represent the more important highway and traffic studies of conditions in the Boston Metropolitan Area. These studies were reviewed in consideration of subsequent developments, including completed major highway projects and changed land-use patterns. These reports and surveys consisted of the following:

a. Report on a Thoroughfare Plan for Boston (1930)
(Origin and Destination Survey of 1927)

b. Master Highway Plan for the Boston Metropolitan Area (1948)
(Origin and Destination Survey of 1945)

c. Report on Traffic Studies for the Boston Metropolitan Area (1957)
(Origin and Destination Survey of 1955)

Additional traffic and planning reports were reviewed, particularly those directly related to specific portions of the study area. The Standard Metropolitan Area of 65 cities and towns, as defined by the 1950 census, was selected as the Traffic Study Area, as shown on Exhibit T-1, and is hereinafter referred to as the Study Area.

Research and application phases of gravity model and traffic assignment procedures were also extensively studied. The projections of traffic growth outlined in both the 1948 Master Highway Plan for the Boston Metropolitan Area and the 1957 Report on Traffic Studies, together with the assignment of traffic volumes to the expressway systems then proposed, were also reviewed and analyzed.

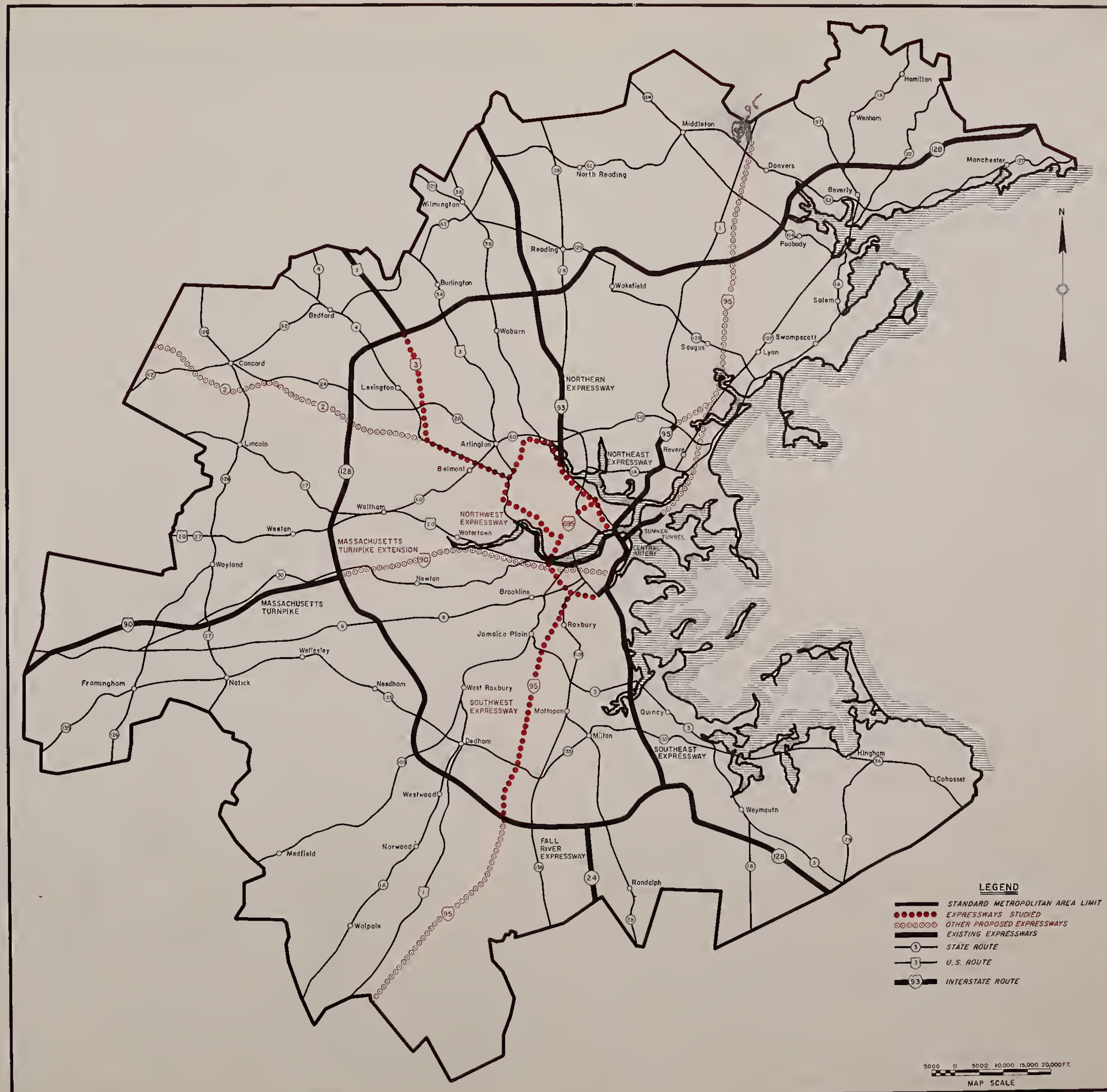


Exhibit T-1
THE TRAFFIC STUDY AREA

REVIEW OF PREVIOUS REPORTS

1930 REPORT ON A THOROUGHFARE PLAN FOR BOSTON

The first comprehensive traffic study of record in the Boston Metropolitan Area was undertaken in 1927 and published in 1930. The report, prepared for the Boston City Planning Board by Robert Whitten, Consultant, was made with the cooperation of the Mayor's Street Traffic Advisory Board and the Division of Metropolitan Planning, and presented the results of the first Origin and Destination (O. & D.) Survey conducted in the Boston Metropolitan Area. The traffic volume increase predicted in the 1930 report, for the period through 1959, coincides closely with the actual increase; the downtown cordon growth factor was predicted as 2.02 for the period 1927-1959, whereas from recorded 1959 counts it was found to be 2.12. On the other hand, the 1945 downtown cordon growth factor (1.0), determined by survey, was actually far less than the 1930 prediction (1.7). The depression of the early 1930's and the cessation of new car production during World War II, together with gasoline rationing, account for the recorded low vehicle travel growth from 1930 to 1945. These conditions offset what would have been an inevitable increase based on population expansion alone.

An impressive feature of the 1930 report is the method employed in the assignment of traffic volumes to a hypothetical highway system. This highway system, illustrated in an exhibit contained therein, consists of a schematic design of radial and circumferential routes closely approximating what are now known as Route 128, the Inner Belt, and the Central Artery. Furthermore, the close resemblance of the Whitten general traffic formula for "future inter-district" traffic to present-day traffic forecasting methods is remarkable. The 1930 data, while primarily of historical interest in the traffic field, was nevertheless reviewed and is briefly described here.

The O. & D. study covered a total area comprising 39 cities and towns including the City of Boston, and consisted of "roadside interviews" at selected stations, a majority of which (105 out of 178 locations) were within the City of Boston. Data for stations located outside of Boston is lacking. The survey and report period covered a wide range of economic conditions experienced in the boom days of the late 1920's and the depression period beginning in 1929 and 1930. In general, the data provided by this study was of little material use in connection with present-day statistical information.

1948 MASTER HIGHWAY PLAN FOR THE BOSTON METROPOLITAN AREA

The Master Highway Plan as developed in the 1948 report for the Boston Metropolitan Area is based upon the 1945 Origin and Destination Survey conducted by the Traffic Division of the Massachusetts Department of Public Works, in cooperation with the then Public Roads Administration, Federal Works Agency. The Boston Metropolitan Area covered by the 1945 survey comprised 24 cities and towns which were subdivided into 138 zones. Zones in the Downtown Boston area were further subdivided into sectors, and the information collected in the survey from the home and roadside interviews was directly related to vehicular trips both originating in and destined for each zone or sector, together with trips which passed through the external cordon stations. Traffic movements for all types of vehicles were thus obtained in 1945 for all station-to-station, station-to-zone, and zone-to-zone movements.

The 1945 O. & D. Survey followed a procedure consisting of an Internal Survey (home, truck, and taxi interviews), and an External Survey (roadside interviews at external cordon points). A five per cent selected sample of homes was visited for the purpose of ascertaining travel habits. In the case of taxicabs and trucks, a ten percent sample was obtained by similar means. The external survey determined the travel habits of persons entering the study area. Simultaneously with the home interview phase of the survey, roadside interviews at 47 external cordon stations were conducted, accounting for 90 percent of all traffic entering or leaving the study area. The results of the internal and external interviews were later expanded to 100 percent on an average daily traffic basis, resulting in a total of 811,053 motor vehicle trips through, into, and within the study area.

1957 REPORT ON TRAFFIC STUDIES FOR THE BOSTON METROPOLITAN AREA

A limited 1955 Origin and Destination Survey was performed for the Department of Public Works, without federal participation, by the firm of Coverdale and Colpitts and was the basis of the 1957 Report on Traffic Studies for the Boston Metropolitan Area. The objective of the 1955 O. & D. survey was the re-evaluation of the 1945 survey data for the primary purpose of examining, after 10 years, the merits thereof in relation to uncompleted portions of the Master Highway Plan of 1948. In addition, the 1955 survey was planned so as to aid in evaluating a proposed Massachusetts Turnpike Extension into Downtown Boston, and to determine the feasibility of an additional harbor-crossing facility.

The study area used for the 1955 O. & D. survey was the same as that for the 1945 study, but trip movement coverage had important variances. For instance, the 1955 interview data on zone-to-zone movements was limited to those movements between the northeast corridor and the downtown-southeast corridor; also, certain station-to-station and station-to-zone data covered in 1945 were omitted in the 1955 survey.

The 1955 O. & D. Survey consisted entirely of roadside interviews which were conducted at 36 locations, 31 of which corresponded with the 1945 external cordon-line stations. The 1945 stations omitted were in the northeast and southeast quadrants of the 1945 study area; the 1955 survey substituted four new harbor-crossing stations, for the purpose of interviewing traffic using the Malden, Wellington, and Mystic River bridges and the Sumner Tunnel, with respect to origins and destinations not only in Downtown Boston zones but also in cities and towns in the study area north and south of these crossings. A fifth new interview station was located on Route 128 at Winter Street in Waltham, in order to supplement data obtained at the 1945 stations in that vicinity. At the four harbor crossings, traffic was interviewed in both directions but in only one direction at all other stations.

INVENTORY OF AVAILABLE SURVEY DATA

A detailed study of present and future vehicular traffic desires, based on available data, was undertaken in June 1959, in conjunction with the review of prior reports. Subsequent to the original 1927 O. & D. survey (39 cities and towns), other O. & D.

surveys were conducted in 1945 and 1955 (both 24 cities and towns), as noted above. However, variations in the geographic scope, the study methods employed, prevailing national and local economic factors, and the overall purposes of each, precluded direct comparison of these surveys.

Preliminary steps in the analytical procedures of this Study included a complete inventory of available data from both the 1945 and 1955 O. & D. surveys. These data comprised information in punch-card and summary trip book form. The 1945 survey punch-cards had been consolidated, during the 1957 study, in a manner similar to the summary trip book compiled at the completion of the 1945 survey. This consolidation resulted in a total of approximately 18,000 cards representing zone-to-zone and station-to-zone vehicular movements for only two classifications, passenger cars and trucks.

The 1955 survey cards were in two groups, external stations and harbor-crossing stations, for a total of 230,000 cards representing external zone to internal zone travel, and zone-to-zone travel between external and internal zones north and south of those stations using the harbor crossings. All 1955 card data were based on nine classifications of motor vehicles. Additional 1955 cards representing various analytical procedures were also inventoried and evaluated. The summary trip books, three for 1945 and fifteen for 1955, contained print-outs of data punched on the foregoing cards.

The 1945 survey covered area-wide zone-to-zone movements, and the 1955 survey produced similar data only at the harbor crossings, and those in limited form; therefore, only meager directly comparable 1945-1955 zone-to-zone data were available for use in this Study. In addition, while the 1955 survey was conducted under normal conditions, the 1945 survey, one of the earlier O. & D. surveys undertaken in the nation, was made near the end of World War II, at which time traffic conditions were far from normal. Although the 1945 survey itself is entirely valid, the distribution, type, and volume of vehicle trips under continuing war-time restrictions on fuel and tires, and the shortage of vehicles, unquestionably resulted in a traffic pattern different from that to be expected under normal conditions.

For the purpose of relating the 1945 and 1955 data to 1959 traffic volumes as a basis for predicting 1975 traffic desires, an analytical procedure was developed to determine whether satisfactory results could be obtained by applying analogous growth-factor methods to the data available from these two surveys.

ANALYSIS OF AVAILABLE SURVEY DATA

All cards and the summary trip books cited above were cross-checked to insure correct survey data comparisons. The differences in techniques and scope of the 1945 and 1955 surveys required complete regrouping of the 1955 data to develop conformity as closely as possible with the 1945 data for use in making trial comparisons. This regrouping to effect direct comparisons was accomplished in the following manner:

a. The 1945 survey data cards were sorted by zone number in ascending order to provide a triangular matrix of zone-to-zone transfers and station-to-zone transfers; the number of elements in this survey matrix totaled 8,204.

b. The 1955 survey data cards were sorted in the same manner, and an electronic computer was used to:
   (1) Consolidate the nine vehicle classifications into two.
   (2) Summarize the external zone-to-station movements.
   (3) Regroup Downtown Boston zone subdivisions to conform with the 1945 survey coding.

With the re-sorted and regrouped cards as input data, the computer was programmed to compute, compare and analyze 1945-1955 ratios of traffic growth factors and traffic distribution patterns where applicable. The resulting comparisons are discussed below.

RESULTS OF TRIAL ANALYSES

An analysis of the computed 1945-to-1955 trip transfer ratios indicated that a station-to-zone extrapolation was feasible and logical from the standpoint of zonal traffic growth and distribution. The growth of external stations likewise maintained, in general, reasonably consistent ratios. It was also found that zone-to-zone ratio comparisons, on the basis of *grouped* zones and also entire municipalities, approximated the traffic growth for comparable areas as checked by various cordon counts. For example, trip transfer ratios of movements between Downtown Boston and individual cities or towns to the north varied from 0.8 to 3.7, for an overall average growth factor of 2.2 for the years 1945-1955.

On the other hand, individual zonal movement factors in this same area varied considerably due in part to the wide range of land-use and sociological changes over that same ten-year period within the separate cities or towns involved. The different survey techniques employed also accounted, in part, for these variations. For these reasons, the possible use of the growth-factor method was considered in detail, resulting in the following conclusions:

a. The inherent assumption that the previous level of service and travel patterns, in this case the restricted war-time travel of 1945, would be valid for projecting travel patterns to 1975 comprised the major weakness in the growth-factor approach.

b. The growth-factor method would require a complete and comprehensive O. & D. survey as basic input data; again this would require a direct dependence upon the 1945 O. & D. survey which would reflect restricted war-time travel.

c. The growth-factor method, requiring the projection of surveyed travel patterns into the future, would necessitate two growth-factor projections, i.e., one for 1945 to 1959, and one for 1959 to 1975.

d. Only limited acceptable zone-to-zone ratios for the time period 1945 to 1955 were available.

e. By the analogous growth-factor methods available at the time of initiation of this Study, where the base year zonal trip transfer volume was zero, the predicted future volume would remain zero; thus, the true growth of many of the outlying areas would not be reflected.

f. Major changes in future land-use patterns as compared to the past would not be effectively taken into account by the growth-factor method.

g. Because an expansion of the study area beyond the 1945

study limit was proposed, an area would be involved in which no basic travel pattern data would be available for extrapolation.

h. A complete socio-economic analysis would be required as part of this Study, which would also provide the input data necessary for a more advanced type of mathematical model.

Certain aspects of the trial analyses substantiated a limited use of growth-factor forecasting methods for prediction of traffic into the near future. However, results expected from the use of this method applied to a 15-year forecast were considered inadequate in reflecting current and projected conditions in the area. The conventional growth-factor forecasting method was therefore discarded. A more advanced and sophisticated mathematical model was adopted, utilizing land-use and sociological data exclusively for prediction, and using the survey data only for calibration purposes. The application of this more advanced method required extensive development under this Study.

SECTION 2 — MATHEMATICAL MODELS FOR TRAFFIC ANALYSIS

HISTORY AND BACKGROUND

THE NEED FOR MATHEMATICAL MODELS IN HIGHWAY PLANNING

Approximately three decades have elapsed since the home and roadside interview techniques and other sampling methods of making origin and destination (O. & D.) surveys in urban areas were first developed. The field methods used, the information obtained, and the method of presentation have changed very little since the earliest published survey. The original purpose of these surveys was to obtain field information that would be useful in the planning and improvement of highway facilities. However, since the data thus obtained reflected only current travel patterns, the problem has always been to determine a satisfactory method of forecasting future travel patterns and trip desires using not only O. & D. survey material but also socio-economic data.

If compatible and thoroughly complete repeated O. & D. surveys were made at sufficiently close intervals, e.g., less than a decade apart, it would be possible to make reasonable short-term predictions of future traffic patterns from the O. & D. trip transfers alone by a method of extrapolating factors based upon various assumptions of analogous growth.[14,32]*

However, with no O. & D. survey data available, or if only one such complete survey has been made which gives a fairly complete picture of inter-area travel movements at some particular point in time, a recently developed and rationally more reliable technique may be used based upon the concepts of synthetic generation and attraction of traffic by means of a mathematical model. In this case, the actual survey data may be used to establish the constants and parameters for a model and to verify and validate the general form of the assumed model.

In the Inner Belt Study an attempt was made to determine present and future traffic movements based upon earlier survey data, particularly that of 1945 and 1955, by the analogous growth method. The results obtained were unsatisfactory and research was then undertaken to develop an effective mathematical model, the needs for which are summarized as follows:

a. A suitable mathematical model or rational formula is required whenever there is insufficient O. & D. data to establish traffic patterns and trip desires.

b. Without some rational model or logical technique, there is great difficulty in extrapolating into the future the presently available traffic data, although some credence might be given to short-term forecasting based on trend lines alone.

c. Mathematical models can be effectively used to determine a complete matrix of present and future trip transfer volumes.

d. In a large, complex urban area served by an extensive existing or proposed expressway system, mathematical models are highly desirable for assignment of both present and future traffic to present and proposed traffic facilities, and for investigation of the effects of design variations upon the resultant expressway assignments, such as route location within a corridor and specific ramp facilities.

*References will be found in the Appendix.

HISTORY OF POTENTIAL, GRAVITY AND INTERACTION MODELS

The concept of a socio-economic gravity model began with the work of E. G. Ravenstein in 1885,[52] wherein it was observed that a population center tends to attract migrants from other centers in direct proportion to its population size and in inverse proportion to its distance therefrom. Moreover, emigration from that area follows the same relationship. This has been called the "P/D relationship" or "population-divided-by-distance rule."

More than thirty years ago this correlating principle was rediscovered by W. J. Reilly in connection with retail marketing and was called "the law of retail gravitation."[27,54]

Reilly stated his law as follows:

> "Two cities attract retail trade . . . from an intermediate city or town in the vicinity of the breaking point, approximately in direct proportion to the population of the two cities and in inverse proportion to the square of the distances from these two cities to the intermediate town."[54]

Starting with the P/D rule, George Kingsley Zipf, a Harvard University philologist-sociologist, proposed in 1942 the following more general theory:

> ". . . the number of persons that move between any two communities in the United States whose respective population are P_1 and P_2 and which are separated by the shortest transportation distance, D, will be proportionate to the ratio $P_1 P_2/D$, subject to the effect of modifying factors."[7]

Movement of materials by rail and motor freight, railway express and parcel post, bus passenger travel, newspaper circulation and telephone calls seem to follow this $P_1 P_2/D$ hypothesis with fair to excellent correlation.[78-81]

In an independent but coextensive work, John Q. Stewart, a Princeton astronomical physicist, extended his almost accidental discovery in 1941 of the application of the P/D rule to the geographical attraction of college undergraduates into the concepts of "population potential," "demographic gravitation," and indeed into a whole system of "social physics." His work has been reported in a large number of publications.[61-66]

This work of Zipf and Stewart was further integrated and generalized in work undertaken at the University of Washington Department of Sociology, in 1950, resulting in the formulation of a so-called "interactance hypothesis" by John A. Cavanaugh and Stuart C. Dodd.[22,28] According to Dodd, the hypothesis of interactance predicts the number of interactions of any one specific kind among people, when observed in groups, from their basic dimensions of time, space, population and per capita activity. Groups of people interact more as they become faster, nearer, larger, and equalized in activity, and the number of interacting yet statistically independent entities clustered in each group constitutes the essential variable. This hypothesis includes the "PP/L" hypothesis, or population product over distance, and the population potential, or "P/L," hypothesis as special cases in which the remaining factors are unities. A condition held in the interactance hypothesis is that uniform density or an even distribution of the population exists over the area studied. This uniform density may hold even though the population may be clustered among human

groups, such as cities of varying sizes, as long as all the groups of any one size tend to be evenly dispersed in the area studied; if the density is not uniform, then some function of the distance other than its first power may give a better fit between the model and the data.

A completely independent outgrowth of the work of Ravenstein resulted in the 1940 promulgation by S. A. Stouffer of the "hypothesis of intervening opportunities." Since this novel and fresh insight still offers great promise for synthetic traffic movement models, it is worthwhile to quote the original hypothesis:

> ". . . this hypothesis assumes . . . no necessary relationship between mobility and distance . . . It proposes that the number of persons going a given distance is directly proportional to the number of opportunities at that distance and inversely proportional to the number of intervening opportunities."[67]

The law of intervening opportunities has already been applied with considerable success to problems in population migration.[13,40] Moreover, all mathematical gravity models can be shown to be merely special cases of this general law, involving particular assumptions with regard to the spatial distribution of the attracting opportunities, as indicated hereinafter.

Another parallel development of importance stemmed from the discovery by Walter Christoller in the early 1930's of certain empirical regularities in the distribution of population in South German cities.[24] This work inspired A. Loesch to contribute to the foundations of the socio-economic science which has come to be called "location theory."[43,44] Together with the related fields of land use and the structure of metropolitan communities, these areas of study have accumulated a vast amount of literature having a direct bearing on the problem of traffic analysis. The more important references are cited here.[2,3,5-10,25-27,29,30,36-39,46,57,68,70-72]

Two excellent reviews of the entire history of gravity and potential models are available in the papers of Gerald Carrothers[21] and Willa Mylroie.[50] The former article contains an extensive bibliography.

More recently there has been discussion and demonstration of the use of linear programming techniques for highway traffic estimation and projection.[4,41,64,65] Linear programming is now a well-established mathematical technique for maximizing or minimizing a linear function of several variables, subject to certain constraints in the form of weak inequalities. Its use in the general area of transportation is now classic, but application to conventional highway traffic engineering has apparently just commenced.

RECENT MATHEMATICAL MODELS FOR HIGHWAY TRAFFIC MOVEMENT

INTRODUCTION

Based upon the impressive heritage of fundamental and fruitful model concepts outlined previously, it was inevitable that significant applications would be made of gravity models and related ideas to traffic planning studies.

These applications to traffic planning are still in the research phase; however, it appears that by use of suitable mathematical models and rational approaches, traffic forecasting and other aspects of urban planning are approaching the status of valid statistical scientific methods.

Because these model techniques have not yet been fully developed by others, the work involved in formulation of a mathematical model as required for the traffic analysis portion of the Inner Belt Study has to a great extent been of the research type, although every effort has been made to use available techniques compatible with sound engineering judgment.

The mathematical model technique applied by others to the selected urban areas of San Diego, Baltimore, Chicago, Washington, D.C., Boston (B.C. Seminar Studies), are discussed below. While all persons concerned with these programs were most cooperative in the exchange of technical information, there remained a distinct atmosphere of uncertainty and continuing experimentation in this field.

THE SAN DIEGO MODEL[17,18,49]

A traffic model was developed by the California Division of Highways under William B. Calland for the San Diego area for the purpose of designing the proper freeway system. The technique used employed both a gravity model for synthetic trip generation and distribution, as well as a routine diversion procedure for assignment of trip transfers to the proposed freeway network.

The gravity model used states that the volume of trips from a zone of origin to a zone of destination is equal to the product of trip generation in the zone of origin times trip generation in the zone of destination times a travel friction factor. In equation form the inter-area formula would be written:

$$V_{1\text{-}2} = KT_1T_2f_{1\text{-}2} = KT_1\,T_2/d^{1.45}$$

where K = constant of proportionality,
$V_{1\text{-}2}$ = volume of trips with origin in zone 1 and destination in zone 2,
T_1 = trip generation in zone 1,
T_2 = trip generation in zone 2,
$f_{1\text{-}2} = 1/d^{1.45}$ = travel friction factor,
and d = airline distance in miles.

Thus, the following points may be observed about this model:

a. The attraction potential was taken identical to the trip generation.
b. The separation effect was measured in terms of airline distance and neither route distance nor travel time were taken into account.
c. The gravity exponent was taken for inter-zonal travel as 1.45 which is a mean value between one and two.
d. The generated trips were manually balanced to fit screen-line and other survey checks.
e. The distribution of trip transfers was carried out in an IBM 650 computer.
f. It was necessary to readjust iteratively the gravitational constant K to force a balance of the total number of trip transfers with the trips generated.

The future inter-zonal traffic obtained from this gravity model was then manually assigned to the network of present and future streets and proposed freeways, using the California time-distance diversion curve, discussed later.

THE BALTIMORE TRANSPORTATION STUDY[74-77]

In the Baltimore Transportation Study, under Alan M. Voorhees, a multipurpose, multimode gravity model was developed. This model involved four trip purposes, namely work trips, commercial trips, social trips, and non-home-based trips. Moreover, attention was given separately to vehicle trips and mass transit trips.

A rather complex and variegated procedure was used to compute the trips of each type generated within each zone. The destinations of these various types were then computed by means of a gravity attraction model based upon land-use statistics of the attracting area, together with the travel time between the destination area and the starting point of the trip.

For mass transit travel, average transit time between zones was used, while for private vehicle trips auto travel time was employed. This effect of travel time on trip attraction was determined by a set of tabulated, empirically-derived travel time factors which were different for each of the four types of trip purpose. These travel time factors were then multiplied by the appropriate land-use attraction statistic to determine the total number of trips to be distributed to each zone.

This model has been used for general long-range planning purposes, but to date it does not appear to be incorporated into an interdependent system with any comparable mechanized traffic assignment procedure, although the BPR assignment program was subsequently employed.

THE CHICAGO AREA TRANSPORTATION STUDY[4,20]

In the Chicago Area Transportation Study (CATS), an elaborate program of total area transportation analysis and planning was undertaken by a team of experts under the overall supervision of J. Douglas Carroll, and including Creighton, Campbell, Bevis, and others.

As it applies to the present program the CATS studies include two items of interest:

a. The development of a traffic model to predict urban traffic volumes.
b. The development of a method of assigning traffic to surface streets, as well as to express routes, and to rapid transit and surface transit facilities.

The CATS traffic model involves a combination of conventional gravity model concepts and novel linear programming techniques. Linear programming was used in the CATS model to minimize inter-area travel frictions. It was necessary to require as programming constraints that all trips generated by a zone must be equal to all trips attracted from that zone, and that an inter-zonal transfer must be zero or a positive quantity, and not greater than a stipulated capacity measure. Two trip categories were used, residential and non-residential. As a result of the complexity of the technique employed it is difficult to express the inter-area travel formula for the CATS method in any reasonably concise equation. The procedure has been checked against O. & D. survey data, using trip length comparisons and correlation coefficients. The model was compared with a more conventional type of gravity model using a sample of 3600 inter-zonal movements. The CATS model was reported, on comparison with the O. & D. data, to have a correlation coefficient of 89 per cent, compared to 78 per cent for the comparable gravity model.

In the Chicago Area Transportation Study a mathematical program was developed for the IBM 704 computer for assigning zone-to-zone movements to a complete urban highway network, assuming a minimum travel time basis. The method finally selected for an assignment program for the Chicago area was based on considerable research by CATS and others. This method is primarily based upon the concept of building minimum-time-path trees from a representation of the street network as discussed later. A number of important points may be made concerning this approach:

a. It assumes and employs the "all-or-none" method presumably supplanting the customary diversion curves.
b. The use of the all-or-none method is found to be both necessary and surprisingly accurate when the volume of movements and density of the streets is sufficiently great.
c. The assignment program may be modified, albeit at great cost, to include the effects of route loading and capacity, which accounts for the principal effects of the diversion curve.

As mentioned, this assignment program was designed for execution by means of electronic data processing machines.

THE BUREAU OF PUBLIC ROADS MODELS AND PROGRAMS[16,45]

The Bureau of Public Roads carried out a program of research activities in the application of gravity models to inter-area travel and in the development of machine assignment procedures. The gravity inter-area travel formula used by the Bureau for home-based trips may be expressed as follows:

$$T_{ij} = \left(P_i \frac{A_j}{A} + P_j \frac{A_i}{A}\right) \frac{K}{D_{ij}^n}$$

where T_{ij} = the total number of primary trips between zones i and j, i.e., with one end at home,

P_i and P_j = the number of primary trips produced in zones i and j by residents of these zones,

A_i and A_j = the number of primary trips attracted to zones i and j by non-residents plus inter-zone trips by residents of those zones,

A = the number of primary trips attracted to all zones,

D_{ij} = the distance between zones i and j, generally expressed in terms of travel time,

K = a constant, and n = an exponent, both to be determined empirically from the analysis.

This formula and a similar one for secondary non-home based trips, are being evaluated by the Bureau using an IBM 704 against the Washington Metropolitan Area 1948 and 1955 O. & D. surveys. For trips produced, P, and attracted, A, actual survey values are used, and the test involved is merely to determine whether any such formula as this will produce reliable results, and, if so, what are the corresponding values of K and n. A program has also been undertaken by the Bureau to relate the P and A factors to land-use statistics.

The Bureau's program for the assignment of traffic to a highway network, reported by Glenn E. Brokke, was based upon a time-ratio concept. With the collaboration of the General Electric Computer Division in Phoenix, Arizona, it was programmed for solution by an IBM 704. This technique employs the same minimum-time-path principle used in the CATS studies, the Detroit

studies, and in this Study. The assignment is on an "all-or-none" basis but with a diversion between two networks, and capacity limitations have to be accounted for by iterative reductions in travel time. The Washington program was amended and revised to account for turning movements.

THE BOSTON COLLEGE SEMINAR RESEARCH BUREAU[69]

Investigations of current gravity model projects included that of the recent Boston College Seminar Research Bureau project. The Boston College technique is based on a selected home interview sample (1000 interviews throughout the Boston metropolitan area which were later expanded statistically) to represent a metropolitan area of 100 cities and towns. Trip frequencies in each of 100 cities and towns of origin on the basis of five purpose categories, were estimated on the basis of 100 interviews in each of ten selected municipalities. These trip origins, generated on this sample basis are then distributed to trip destinations using an inter-area travel formula programmed for an IBM 650 electronic computer.

GENERAL CRITICISMS

In view of the aspect of continuing experimentation exemplified in the applications cited, it became apparent that if a gravity model were to be used at all, a new, original, sound and scientific approach to the engineering requirements of this Study would be mandatory. This new approach, it was recognized, would be required to take into account the following factors:

a. The objective of this Study was the planning, location, and basic design of the Inner Belt and Expressway System, and neither an urban area traffic study in itself, nor research and development of advanced traffic analysis techniques.
b. Although thus limited in objective, the accompanying traffic analysis, in order to arrive at meaningful results, must take into account the effects on these expressways of all traffic activity in the Boston urban area.
c. The scope of the usage of the mathematical model being thus bounded, the model as an engineering tool must encompass the entire traffic problem in as brief and straightforward a method as possible.

RECENT DIVERSION PROCEDURES

INTRODUCTION

After a complete transfer matrix either for present or for future inter-area trip movements has been determined, it is then necessary to estimate the loading of these trips onto the expressway network. In order to accomplish this objective, some rational method for assigning traffic to the alternative routes is required. This process involves the use of a distribution relationship or diversion curve as outlined below.

CURRENTLY USED DIVERSION CURVES AND FORMULAE

Several types of diversion relations are now in current use, such as the following:

a. The time-ratio curve in the BPR "Guide for Forecasting Traffic on the Interstate System" of October 15, 1956.
b. The distance-ratio and speed-ratio curves used in the Detroit studies.
c. The time-and-distance differential curve used in the California studies.
d. The so-called "all-or-none" law.

The first three of these methods have been discussed by Glenn Brokke:

a. "The Bureau's time-ratio curve relates the percentage of trips using a freeway facility based on the ratio of the travel time via the freeway to the travel time via the best alternate route."
b. "The speed-ratio curves developed for the Detroit Area Transportation Study consist of a family of curves where the percentage of freeway use is related to speed ratio and distance ratio. Because these curves represent a three-dimensional surface with an undefined mathematical relationship, they are difficult to use in a computer application."
c. "The California time-and-distance curve consists of a family of hyperbolas where equal time and distance on the freeway as compared to the best alternate route will assign 50 per cent of the traffic to the freeway."[16]

Thus all presently used assignment procedures employ no more than two times, D_1, D_2, and the corresponding two distances, d_1, d_2. These then assume a general diversion relation of the form:

$$P = \text{Function of } (D_1, D_2, d_1, d_2)$$

where P = fraction of traffic assigned to the expressway or principal route (subscript 1),
$1-P$ = fraction assigned to the other single alternative mode or path (subscript 2),
D = time on a route or path,
and d = distance on a route or path.

The Detroit empirical diversion relation is based on the time *ratio* D_1/D_2 and distance *ratio* d_1/d_2, and therefore can be represented in the form:

$$P = \text{Function of } (D_1/D_2, d_1/d_2)$$

The California diversion as well as several others which have been employed in the past are based upon the time saved or time *difference* D_2 minus D_1, and distance saved or distance *difference* d_2 minus d_1. These diversion relations would take the form:

$$P = \text{Function of } (D_2-D_1, d_2-d_1)$$

The simplest of the above three cited practices is the Bureau (Washington) curve which assumes that diversion is insensitive to distance and merely depends upon time-ratio alone in the form:

$$P = \text{Function of } (D_1/D_2)$$

However, for many purposes of computation, especially where a large number of movements are involved and where either corridor traffic or free assignment traffic (i.e., without capacity restriction) is desired, the so-called "all-or-none" time diversion law may be used, where either the difference form,

$$P = \frac{1}{2}\left[\frac{(D_2 - D_1) + |D_2 - D_1|}{|D_2 - D_1|}\right]$$

or the ratio form,

$$P = \frac{1}{2}\left[1 + \frac{1-(D_1 / D_2)}{\left|1-(D_1 / D_2)\right|}\right]$$

may be adopted, yielding the same results whether based on time ratio or time difference. This formula, which merely assumes that all traffic is diverted to the quickest path, is illustrated in Exhibit T-2, and may be considered the limiting case for any number of similar S-shaped curves.

GENERAL CRITICISMS

Any rational method of assigning traffic movements to an expressway network overlaying a complex street pattern should take account of the fact that any given movement will actually be distributed over a large number of possible paths between the two trip ends. The only regularization principle which orders this otherwise chaotic system is that with large numbers of individual movements there is both a logical and a measurable tendency to have a greater fraction of the given movement travel over the quicker or shorter paths.

The National Policy of the American Association of State Highway Officials[51] recommends for assignment the use of a diversion curve displayed therein, based on Highway Research Bulletin No. 61, "Traffic Assignment," 1952, cited in a footnote thereto. Research of the technical literature concerning assignment procedures revealed that considerable work had been accomplished in this field since the publication of that Bulletin.[16,19,47,58,73]

Several investigators have engaged in refinement or alteration of the original diversion curves to accommodate particular situations.[15,73] Probably the most significant findings, however, are:

a. "Those who have advocated diversion curves for use in traffic assignment have done so to meet the requirements of designers who ask the traffic engineer to tell them how many vehicles will use a ramp or a facility in the peak hours. The use of these empirical curves may be useful for such assignments to an already determined line.

"But it is also possible that diversion curves are wrong. They have been established by making observation of an existing system's usage. Naturally, such systems tend to be in traffic equilibrium — that is, 'traffic seeks its own level.' It follows, therefore, that diversion rates are a function of the capacities and traffic pressures in the region being examined. If the expressway being measured for diversion had either fewer or more lanes, it seems quite clear that correspondingly greater or less traffic would use it and, therefore, diversion rates would change . . .

"In sum, there are quite apparent and inherent weaknesses in diversion curves as they are developed and used today. One of the greatest is that such curves provide an answer which is unrealistic by definition and yet is assumed to be correct. Therefore, the analyst does not truly know what he has obtained because the elaborate construction of the diversion curve merely produces an answer . . .

"A simulation of traffic flow would, if properly done, produce a result identical with the current usage of the urban network. In other words, the result of accurate flow simulation would be a current traffic flow map . . .

"To the planner, then, the extent of driver diversion is not visible on a traffic flow map and it is quite difficult to read the need for improved routes where the overloads are evenly distributed throughout the system. In short, needs cannot be determined by reading a traffic flow map. It is precisely for this reason that origin-destination data were collected.

"It is possible to confuse a request for realism with traffic assignment as it can be of use to the planner. The planner needs to know where an improvement in capacity will do the most good. This method of traffic assignment by being 'unrealistic' is able to magnify the points of great system stress and thus insure most judicious placement of improvements.

"Also, when a plan is finalized, this method can be modified so that capacity restraints are introduced to the network and trips are diverted from congested to alternate routes, thus more realistically simulating predicted usage. In this fashion, capacities can be dealt with explicitly and the extent of diversion caused by capacity constraints can be measured. It is of substantial interest to note that this cannot be achieved by diversion curves. They are not sensitive to capacity constraints excepting those which were in effect when these curves were empirically established."[20]

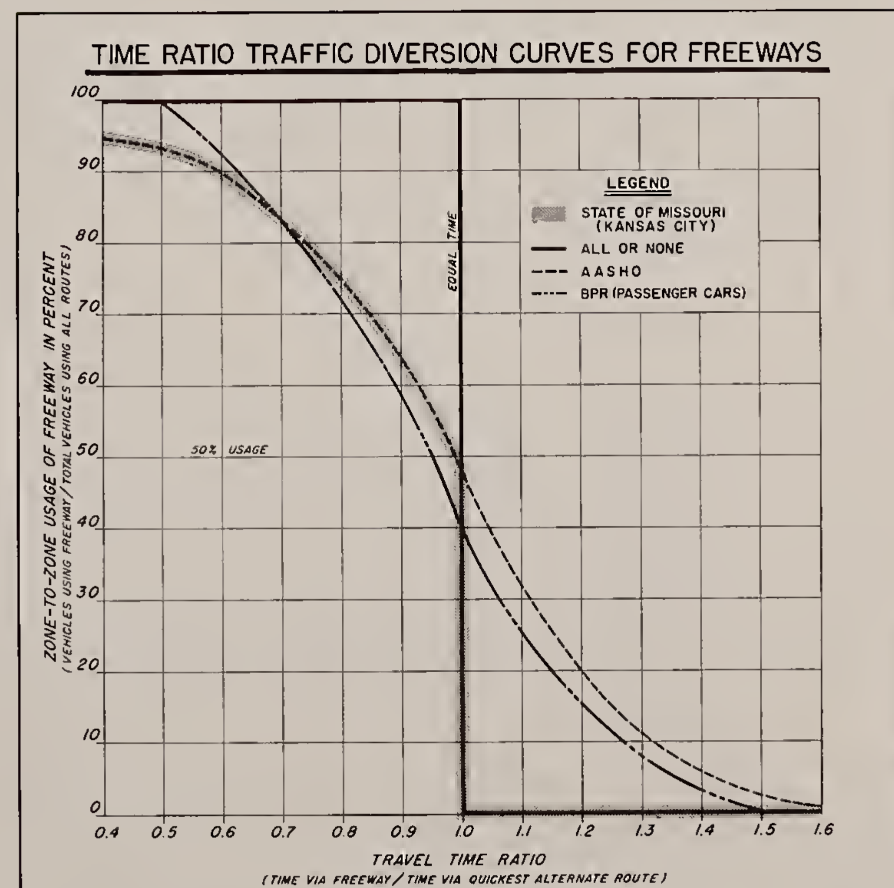


Exhibit T-2

b. "I have previously discussed the 'All or Nothing' and 'Diversion Curve' methods and mentioned that we used both methods in every one of our assignments. We have now concluded that in a densely populated large urban area with a comprehensive freeway system offering many alternative freeway routings, that the 'All or Nothing' method is the most practical method to use."[56]

THE MODEL

INTRODUCTION

As is evident from the foregoing discussion of the history and background of mathematical models, the problem of representing traffic in a mathematical model consists of three distinct but more or less interdependent phases, namely traffic generation, distribution, and assignment.

a. Traffic *generation* is concerned with the questions of what gives rise to traffic; that is, in any given portion or zone of an urban area, how much traffic is originated by the people, plant, and activities which are unique to that zone.

b. Traffic *distribution* is concerned with the question of where that generated traffic desires to go; that is, of the traffic generated in that zone, how much is attracted to each of the other zones of the urban area by virtue of the people, plant, and activities unique to each of the other zones.

c. Traffic *assignment* is concerned with the question of the routes which traffic will take, or will desire to take, when the generating zones, or origins, and attracting zones, or destinations, are known for all fractions of the urban traffic.

The generation of traffic to be ascribed to each zone may be based upon an origin-destination field study, the projection of values obtained from such a study, or upon independently-determined sociological data. The distribution of such generated traffic is dependent primarily upon two factors, the relative attractiveness of each zone for the traffic generated in any zone, and the relative geographic separation of the zones. The assignment of traffic must be based upon some measure of the relative merit of the several possible routes between any two zones. Mathematical investigation reveals, as explained below, that the problems of relative separation of zones, and of relative merit of routes between zones, can both be solved in a single analysis, an indication of the aforementioned interdependence.

THE NEED FOR A SINGLE-PURPOSE MODEL

As discussed previously, all prior and current traffic models for various reasons were deemed too complicated and unsuitable for the present purposes. It is important to reiterate that most of the currently used gravity traffic models are still very much in the research phase. Particularly in the case of those employed by Voorhees,[74-77] these are multimode, multipurpose models which deal separately with all modes of travel and transit and with all major trip purposes. To establish a model of such complexity, which would be particularly suited to the Boston area, was not within the scope of this Study. Neither was it considered feasible to employ an existing model specifically developed for another area. The principal objectives, therefore, were to:

a. Develop a new and simple model which would in a single mathematical system:

(1) Generate realistic synthetic trip transfer volumes solely from sociological and land-use data, without recourse to sampling in the base year.

(2) Distribute this traffic to various zones of attraction solely on the basis of travel times and sociological and land-use data.

(3) Mechanically assign the resultant computed trip transfers to suitably represented street networks and expressway systems.

b. Develop a model which would satisfy all the above conditions and which could be programmed for a large-scale electronic computer.

It was decided, based on these observations, to develop such an original model. Since this Study contained no provision for either experimental development of this nature nor a continuing, long-run investigation, it became mandatory to establish a stark and clear-cut procedure. Thus the model finally adopted employed simplifications which were judged to be entirely consonant with the objectives previously cited.

MINIMUM TIME PATHS THROUGH THE HIGHWAY NETWORK

INTRODUCTION

Exclusive of major arterial streets and expressways, there exist well over 50,000 individual street links in the Boston Metropolitan Area. It is inconceivable that such a large and randomly oriented network could be represented in complete detail for traffic flow analysis. Therefore, a suitably skeletonized network was devised to serve as an equivalent street network, although the expressway network together with accompanying ramp facilities was represented in strict one-to-one detail. These techniques are discussed below.

THE DEFINITION OF A NETWORK

By a NETWORK in this report is meant an interconnected system of paths consisting of intersection points called NODES joined by individual route paths called LINKS. The nodes are defined and specified by means of their X-Y coordinates on the Massachusetts Grid System.

The links are given directional sense such that link ij joining node i to node j is not the same as link ji joining node j to node i. Each such *unidirectional* link is defined and specified by means of the coordinates of each of its terminals in the fashion:

$$\text{LINK } ij = [(X_i,\ Y_i),\ (X_j,\ Y_j)]$$

$$\text{LINK } ji = [(X_j,\ Y_j),\ (X_i,\ Y_i)]$$

The DISTANCE of each and every link can be computed in terms of the square root of the sums of the squares of its coordinate differences in the form:

$$d_{ij} = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}$$

With a definite value of SPEED, V_{ij}, assigned to each link, it is then possible to determine a specific value of LINK TRAVEL TIME, D_{ij}, in the fashion:

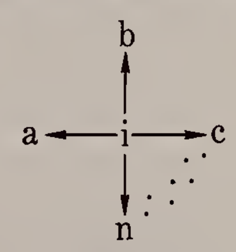
$$D_{ij} = \frac{d_{ij}}{V_{ij}}$$

A complete network description can always be given in terms of the set of all NODES-PLUS-NODE-NEIGHBORS. The NEIGHBOR NODES adjacent to each node are all those points which can be reached from it over a single existing link. Thus a set of node-

plus-neighbors defines a STAR of radial links which may be represented in coordinate fashion:

$$\text{NODE}: (X_i, Y_i) : \left.\begin{matrix}(X_a, Y_a)\\(X_b, Y_b)\\(X_c, Y_c)\\\cdots\cdots\cdots\\(X_n, Y_n)\end{matrix}\right\}\text{NODE NEIGHBORS}$$

Any movement over this star will always be assumed to be radial *outward* for directional sense. That is:



Thus the set of stars originating from each and every node specifies all possible movements over existing network links.

Any route or PATH through the network can be described by specifying the chain of ordered coordinates defining the NODES-ON-ROUTE. This gives a representation for the path ij in the form:

$$\begin{matrix} i & \longrightarrow & u & \longrightarrow & v & \longrightarrow & \cdots & \longrightarrow & j \\ (X_i, Y_i) & & (X_u, Y_u) & & (X_v, Y_v) & & \cdots & & (X_j, Y_j) \end{matrix}$$

A CLOSED PATH or ROUND TRIP is any path which begins and ends at the same node in either of two fashions:

$$(1): \underline{i} \rightarrow u \rightarrow v \rightarrow \underline{j} \rightarrow v \rightarrow u \rightarrow \underline{i}$$

$$(2): \underline{i} \rightarrow u \rightarrow v \rightarrow \underline{j} \rightarrow x \rightarrow y \rightarrow z \rightarrow \underline{i}$$

Since these paths may be redrawn:

$$(1): \; i \rightleftarrows u \rightleftarrows v \rightleftarrows j$$

$$(2): \; i \begin{matrix} \longrightarrow u \longrightarrow v \longrightarrow \\ \longleftarrow z \longleftarrow y \longleftarrow x \longleftarrow \end{matrix} j$$

it is clear that a round trip may be made using a different path for the return leg from that used for the forward leg.

THE SPIDER NET AS AN EQUIVALENT STREET NETWORK

In lieu of representing the actual street network, an equivalent network was established using essentially the straight line paths between area centroids as network links roughly equivalent to the actual street pattern. Here, then, the nodes are the same as zone or sector centroids while the links which join any pair of nodes are the paths over which all vehicle trips are presumed to travel. This seemingly arbitrary technique can lead to reasonable results as discussed hereinafter. By the precedent set for this technique in the Detroit Study,[34] the resultant network of linked area centroids has come to be called a "spider-net." One-way streets and similar unidirectional asymmetries have been introduced by suitable handling of the node neighbors.

NETWORK REPRESENTATION OF EXPRESSWAYS AND RAMP FACILITIES

The existing and proposed expressway network for the Metropolitan Area was represented by a similar set of nodes and links, representing each and every ramp facility and expressway intersection. Unidirectional movements, as in expressway main lines, and bilateral asymmetry, such as in the case of expressway ramps, are secured through the device of the node-plus-neighbors technique. The details of this procedure are indicated in a subsequent paragraph.

CALCULATION OF LINK DISTANCE AND TRAVEL TIME

As indicated above, each link distance is computed directly from the coordinates of the terminal nodes of that link. The travel time for each link was computed using speeds which were assigned following procedures discussed later. Since the links are themselves unidirectional it was possible to have route speeds which were significantly different in the two directions of travel. Once a travel time is determined for each link, it is possible to conduct a search for the minimum-time path between any origin and any destination in the network.

BUILDING THE MINIMUM-TIME-PATH TREES

The crucial element required both for the distribution of generated traffic and also for the assignment of the resultant trip transfers to present and projected expressway facilities is the determination of the set of *minimum-time-path trees* radiating from each of the more than two hundred fifty volume-producing nodes assigned to the Boston Metropolitan Area.

The logical steps involved in mechanically determining these paths and in building the resultant trees have been published by a number of writers.[1,34,35,48] These procedures were modified and mechanized as required for incorporation into the computer programs prepared for this Study. As finally programmed, the expressway network together with its access and egress ramps, was appended by stages to the spider-net equivalent street network. At each such stage a revised set of trees was obtained, reflecting the reduction in time for average movements associated with the improved facilities.

THE ESTABLISHMENT OF A GRAVITY MODEL

INTRODUCTION

As previously noted, it was decided to employ the simplest possible model which would yield reliable present and future data on traffic movements. This model was then calibrated as reported later against the O. & D. survey data of 1945 and against screen-line counts of 1955 and 1959.

The logic underlying the use and establishment of this model is discussed below. It is perhaps important to point out that all generation, attraction, and distribution of trips is based upon the assumption of *round trips* made within the average *twenty-four-hour* day. That is, it is expected that a trip generated at a given node on the average day will return to that node within that same day. It is evident that this behavior holds for all but a negligible fraction of home-to-work trips, and it is true for the majority of commercial trips within the area, although of course not true for the itinerant salesman or similar trip. Thus a trip may be generated in a zone, distributed to its attracting zone, and then reapplied from this attracting zone back to its generating zone, without the necessity of again being generated at this zone of attraction.

THE GENERATION OF TRIPS

The model assumes that the generation potential, G_i, for any area, can be assumed to be a two-term quantity of the form:

$$G_i = k\ (c_i P_i + dR_i)$$

where k = generation constant,
c_i = car ownership,
P_i = area population,
d = scaling constant,
and R_i = modifying statistic.

The basis for the generation model lies in the fact that the great majority of automobile trips are home-based trips for which the area population and vehicle ownership statistics are the principal factors producing traffic in a given area. The choice of a simple product for the combining law is based on certain results from the Washington and Baltimore studies which clearly indicate that areas of equal population produce automobile trips in direct proportion to car ownership.[59,74] Thus if either the population becomes small or the car ownership is low, the volume of trips generated will be accordingly small.

However, there exist obvious non-conforming patterns which are ordinarily handled by other components, purposes, or modes. Here these are all included in the "dR_i" correction. Ideally this modifying socio-economic factor, R_i, would be a statistic such that the deviational correlation:

$$r = \frac{\sum \Delta_i R_i}{\sqrt{\sum \Delta_i^2 \cdot \sum R_i^2}}$$

reaches a maximum, where the deviation, Δ_i, is the computed difference between the observed or surveyed trip generation and that predicted using kc_iP_i, alone. This deviation would take the form:

$$\Delta_i = (G_i)_{\text{observed}} - (kc_i P_i)_{\text{computed}}$$

Actually, several statistics were tried for R_i, including employment, population density, and employment density. The final model used employment density for R_i, as explained later.

THE ATTRACTION OF TRIPS

The attraction potential, Q_i, was similarly assumed to be a two-component quantity, of the form:

$$Q_j = E_j + bF_j$$

where E_j = total area employment,
b = scaling constant,
and F_j = modifying statistic.

Ideally, F_i should be a quantity as nearly independent as possible from E_i, yet one which correlates as closely as possible with the residual attraction errors using E_i alone. This is directly analogous to the situation between c_iP_i and R_i in the case of generated traffic, as discussed above. The final model used settled on the use of retail employment density for F_i, as later outlined.

THE DISTRIBUTION OF TRIPS

The actual round trip movements between an area of generation and an area of attraction will, of course, depend upon the travel time-and-distance between the two areas. It is reasonable to assume that a measure of this separation effect will be the minimum-time-path determined from the tree-building program described above.

As previously indicated, most currently-used gravity models assume that this time-distance effect enters as an inverse power law, such that the attracted round trips, G_{ij}, between "i" and "j" would be expressed by the formula:

$$G_{ij} = K \frac{G_i Q_j}{D_{ij}^n}$$

where K = gravitational constant,
G_i = generation potential,
Q_j = attraction potential,
D_{ij} = time-distance,
and n = constant exponent.

Voorhees and others have noted that significantly better correlation is achieved when D_{ij} is raised to a variable exponent, and includes a suitable terminal time for both ends of the trip, rather than using the route travel time, alone.[76]

Significant insight into the separation effect, $1/D_{ij}^n$, can be obtained by applying the law of intervening opportunities[67] to this situation, thus establishing the probable value of "n" on rational grounds. Consider the attraction of an area "j" for round trips generated within an area "i," when the minimum time for automotive travel from "i" to "j" is known or calculated to be D_{ij}. Under the Stouffer hypothesis the attraction ratio, a_{ij}, would be calculated from the formula:

$$a_{ij} = \frac{Q_j}{\int_0^{D_{ij}} dQ}$$

where the integral is summed over all areas of attraction for which $D_{ik} \leq D_{ij}$, which is within the isochrone, or time contour, which passes through the zone center of area "j."

First, under a broad class of circumstances, it might be reasonable to assume that the attraction potential, Q_i, is distributed fairly uniformly over the metropolitan area. If this were true, then

$$dQ \cong K \cdot D \cdot dD, \quad K = \text{constant}$$

and

$$\int_0^{D_{ij}} dQ = \frac{K}{2} \cdot D_{ij}^2$$

This results in an inverse-square-law attraction, namely:

$$a_{ij} = \frac{2 \cdot Q_j}{K \cdot D_{ij}^2}$$

On the other hand, particularly for the attraction of trips from the Central Business District (CBD), it is generally true that the density of attraction potential decreases with increasing distance from the CBD. If we then assume:

$$dQ \cong H \cdot dD, \quad H = \text{constant}$$

then

$$\int dQ = H \cdot D_{ij}$$

and
$$a_{ij} = \frac{Q_j}{H \cdot D_{ij}}$$
which yields inverse-distance attraction.

These results demonstrate clearly the difficulties which may develop due to use of a gravity model which employs a constant value of "n." Therefore, it was decided to assume an arbitrary function of distance of the form:

$$f(D_{ij}) = \gamma + \delta D_{ij} + \epsilon D_{ij}^2$$

which includes the linear and square laws as very special cases, and to carry out a program of parameter fitting for γ, δ, and ϵ based primarily on the 1945 O. & D. survey data. This parameter-fitting program, discussed in Section 3, ultimately resulted in the conclusion that an exponent of two would be adequate for the purpose of the present Study. This function is plotted in Exhibit T-3 in terms of Σt rather than D_{ij}, since the function of time-distance used is the travel time, Σt. In Exhibit T-3, the values of $\gamma = 0$, $\delta = 0$, and $\epsilon = 1$ have been substituted in the equation and the resulting curve plotted, to represent an exponent of two, or the square law.

Moreover, in order to minimize the task of fitting the model, it was decided to arrange the inter-area attraction formula in the form of a dimensionless attraction coefficient, A_{ij}, such that when summed over all zones of attraction the total coefficient would be normalized to unity. That is:

$$\sum_{j=1}^{n} A_{ij} = 1.0$$

Physically, this ensures that all generated round trips are merely distributed to all zones of attraction. This useful result is accomplished by defining:

$$A_{ij} = \frac{\dfrac{Q_i}{f(D_{ij})}}{\displaystyle\sum_{k=1}^{n} \frac{Q_k}{f(D_{ik})}}$$

where, as stated, the denominator is summed over all areas of attraction.

THE COMPLETED MODEL

Any round trip transfer of traffic volume from one zone i to another zone j may be stated as the product of the generation

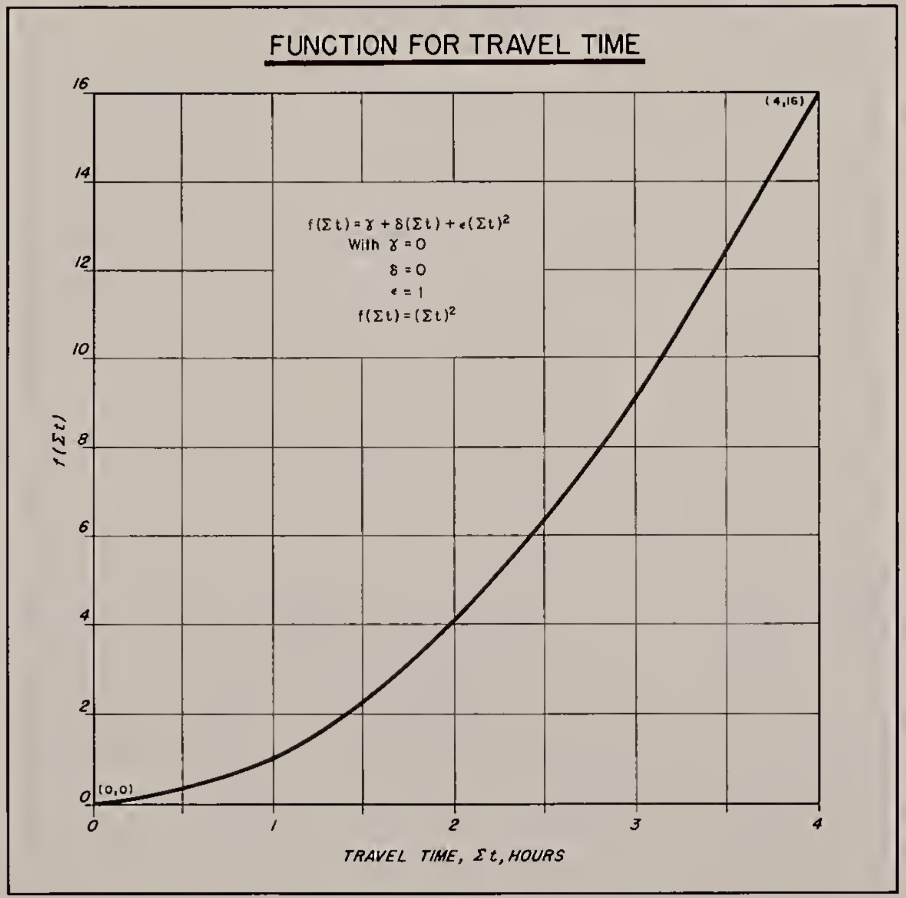


Exhibit T-3

of traffic in zone i and the attraction of zone j for zone i, or:

$$T_{ij} = G_i A_{ij}$$

Substituting the values derived for these, the complete gravity model ready for scaling and parameter fitting thus is:

$$T_{ij} = K(c_i P_i + d R_i) \left[\frac{\dfrac{Q_j}{f(D_{ij})}}{\displaystyle\sum_{k=1}^{n} \frac{Q_k}{f(D_{ik})}} \right]$$

in which
$$Q_j = E_j + bF_j$$
and
$$f(D_{ij}) = \gamma + \delta D_{ij} + \epsilon D_{ij}^2$$

LOADING THE NETWORK

ASSIGNMENT OF TRIP TRANSFERS TO SPECIFIC LINKS

Once the entire set of minimum-time-path trees has been established for each volume-producing node or zone of origin, $i = 1, 2, \ldots, N$, it is then possible to load the entire trip transfer matrix, T_{ij}, onto the set of trees. Since, in general, each link coincides with more than one tree, the total link loading is obtained by summing over all trees in which the particular link occurs.

This procedure may be alternatively conceived in terms of the so-called LINK TRANSFER INCIDENCE MATRIX which gives for each and every link a listing of all trip transfers and the volume of each which would be assigned to that link. Since there are over ten thousand links and more than sixty thousand transfers in the final 1975 system for the Standard Metropolitan Area, the actual printed display of this complete matrix assumes voluminous proportions.

A third alternative loading concept is the TRANSFER LINK INCIDENCE MATRIX which gives for each trip transfer a listing of each and every link to which it would be assigned. For the same reasons as above, a recorded print-out of this matrix is also of extremely large magnitude.

The logical simplicity of the results of application of the gravity model depend crucially upon the "all-or-none" principle of assignment to a single set of minimum time-path trees. Such an assignment is referred to throughout this Study as a FREE ASSIGNMENT.

TRAFFIC ASSIGNMENTS AND SIMULATED TRAFFIC FLOW

From direct observation, validated by measurement and supported by logical analysis, it is known that the average speed of the vehicle stream upon any highway section depends upon the traffic density. As the traffic density, in number of vehicles per mile, becomes very small the average speed will approach its maximum limit, while with increasing traffic density the speed

will gradually decrease until at maximum density the vehicle stream will reach standstill. Multiplication then gives the result that every section has a maximum capacity of traffic volume, in number of vehicles per hour, which is reached when the average speed is less than the maximum speed, generally about midway between standstill and maximum speed.

The implication for the present problem is simply that if it were desired to simulate traffic flow, the minimum-time-path trees for any network would necessarily depend upon the network loading. But the loading, in turn, depends upon trip desires, which in their turn depend upon the minimum travel times. This in turn implies that a rational and logical simulated-flow assignment procedure, which attempted to predict operational use of the entire system as opposed to assignments for planning and design purposes, would involve a computing program vastly more complicated than that employed here, which in fact as it stands taxes the storage of a large-scale computer such as an IBM 704 or 7090 to the limit.

Any rational program for simulated-flow assignment volumes would have to provide for the following rational observations:

a. The inter-area transfers are distributed over a *set* of alternative paths in probable inverse proportion to a weighted time-distance.

b. The travel time of any link and therefore of any path which includes the link will depend upon the total volume on the link.

c. The distribution of generated trips will depend upon the relative separation of every attraction area in terms of travel time.

A program of this complexity cannot be undertaken by any presently available computing machine except on an iterative basis, in which the machine is programmed to operate in an extensive sequence of converging cycles of iteration. Although such a program has been very recently carried out by others for a city represented by a relatively small net, current computer technology does not lend itself to such computation for the magnitude of the net used in the present Study.

For the present purposes, then, it is intended to carry out all planning and design on free assignment and capacity-restricted assignment bases, as opposed to a simulated-flow basis, since all design changes can be investigated on the basis of their tendencies to increase or decrease computed link loadings. These matters are further discussed in Section 4.

CAPACITY-RESTRICTED ASSIGNMENT

In order to determine information on a capacity-restricted basis, a program was developed which in essence uses the data resulting from the free assignment program as a point of departure. This is the TIme-Saving Rank-Order method, hereinafter referred to as the "TISRO" method. The title of this method refers to the fact that by definition under free assignment each trip which uses the expressway system saves times by so doing, rather than by using the street system alone. These trips are listed, or ranked, in order of this time-saving, to be used under this method. The application is explained below:

a. There has previously been assigned to the network a set of trip transfer volumes generally in excess of capacity, on the basis of free assignment.

b. There are made available in the computer system lists of the trip-transfer travel-time from any traffic generating point to any other point, via the streets alone and via the expressway-plus-streets in cases where such traffic is alternately assigned to expressways.

c. For each group of trips, or trip transfer, from origin to destination, the travel time via the expressway-plus-streets is subtracted from the travel time via the streets alone; the remainder is the time-saving accomplished by using expressways for some portion of the trip.

d. These time-savings are then placed in a "positive-saving" list in order of magnitude, with the greatest time-saving at the top of the list, together with their attendant origins, destinations, and volumes. Transfers having a difference of zero are placed in a second, or "zero-saving" list.

e. Each segment of the expressway system, excluding ramps, is given a number representing the design capacity, above which traffic volumes must not be assigned on that segment.

f. Trip transfer volumes are then assigned to the network in order of their appearance on the list of time-savings just previously prepared. It is evident that those transfers having the greatest time-saving would be assigned first.

g. As each transfer which uses a segment of the expressway is assigned to each link it uses, the total volume assigned to that link up to that point is compared with the capacity figure previously stipulated for that link.

h. When the total volume assigned to a link attains the capacity figure, all other transfers which would use that link beyond capacity and obviously have lesser time-savings, are removed from the positive-saving list and placed on the zero-saving list.

i. When the positive-saving list has been exhausted, there appears on each expressway link a figure not greater than either the capacity figure or the figure which appeared in the previous free assignment, if it was originally less than capacity. All those transfers which have been denied use of the expressway appear on the zero-saving list, which is printed out in such form as to be applicable to the design, and these transfers are also assigned to the street network, thus providing additionol valuable information for determination of the necessity for street improvement or additional facilities, or both.

The development of the model system theory was thus accomplished. At this stage of development it stands as a valuable extension of prior knowledge to an engineering procedure of extreme utility in traffic analysis such as was necessary for this Study, as well as for further work by others in keeping the results current and for additional applications. Considerable work has been done by others in the field of such model theory since the initiation of this Study; this work continues, however, to be of a research nature for urban planning study purposes. The present model is the result of a direct application of such theory to engineering location ond design consideration for an expressway system in a large metropolitan area. The implementation and application of the model theory here developed is discussed extensively in the following Section.

SECTION 3 – APPLICATION OF THE PRESENT MODEL

REPRESENTATION OF THE PROBLEM

INTRODUCTION

As stated previously, it was recognized in an early stage of the development of the mathematical model theory that the facilities of a high-speed electronic computer would be required to accomplish this complex task of determining design traffic volumes for the expressways. The theory of single-purpose mathematical model generation and assignment having been formulated and developed, it remained to implement the theory by selecting adequate parameters to represent the modifying terms of the model, preparing input data for computation, and preparing programs for the computer. The input data preparation consists essentially of:

a. Representation of the roadway systems in spider-net form.
b. Selection of representative speeds for the roadways.
c. Preparation of sociological input data.

REPRESENTATION OF THE ROADWAY SYSTEMS

THE SPIDER NETWORK FOR STREETS

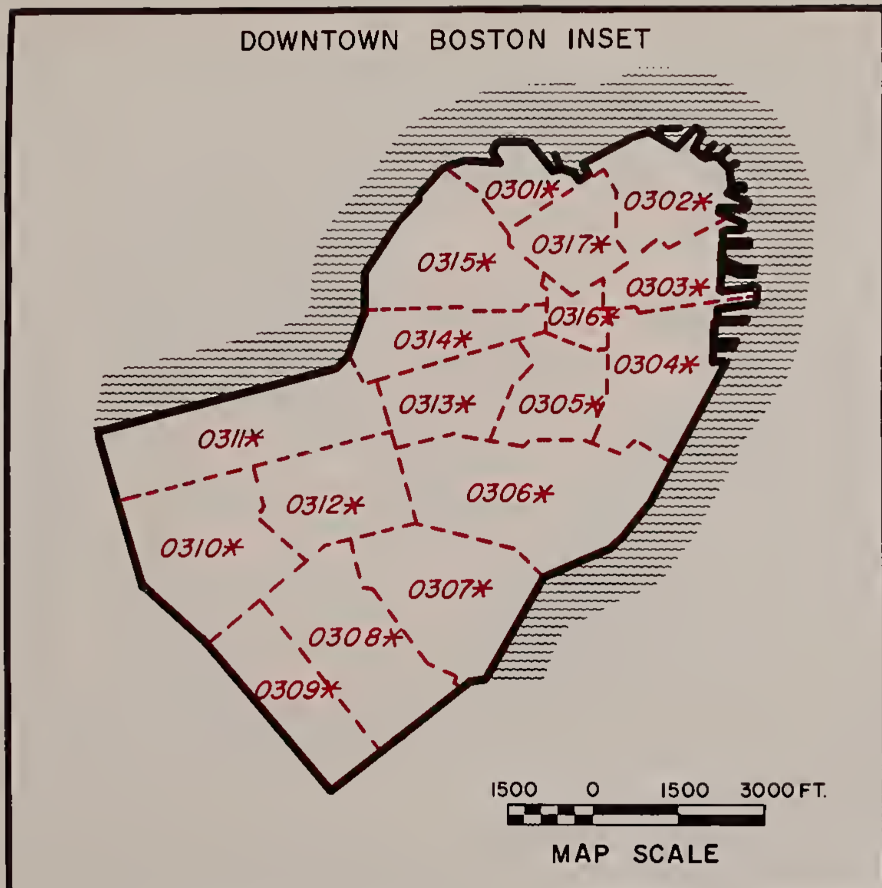
A preliminary and essential step in the process of computing traffic assignments is the preparation of a synthetic highway system. This synthetic highway system, or spider network, was prepared based on the assumption that all travel is between or through the centroid nodes of the zones and sectors within the Traffic Study Area, shown on Exhibit T-4. Refinements were made in the spider network consisting of additional node points; an explanation of these various types of nodes comprising the base spider network follows:

Traffic Generating Zonal and Sector Nodes.

These node points have two functions:

a. To represent sources of traffic generation and points of attraction for the gravity model program, and
b. To represent intersections of traffic flow in the street system.

Exhibit T-4
CITY AND TOWN LOCATION MAP



Non-Traffic-Generating Sector Nodes

The zones in some areas were divided into sectors to approximate more closely the existing complex street system; these sector nodes transmit traffic flow but are not used as traffic generators or attractors.

Bottleneck Nodes

Certain physical barriers, such as the Mystic and Charles Rivers, for example, preclude certain zone-to-zone movements other than at particular locations, such as bridges. All traffic flow between such zones must of necessity use these crossings, and bottleneck nodes have been introduced at these locations to represent such barrier crossing-points, thereby requiring traffic to funnel through these points to cross the barrier.

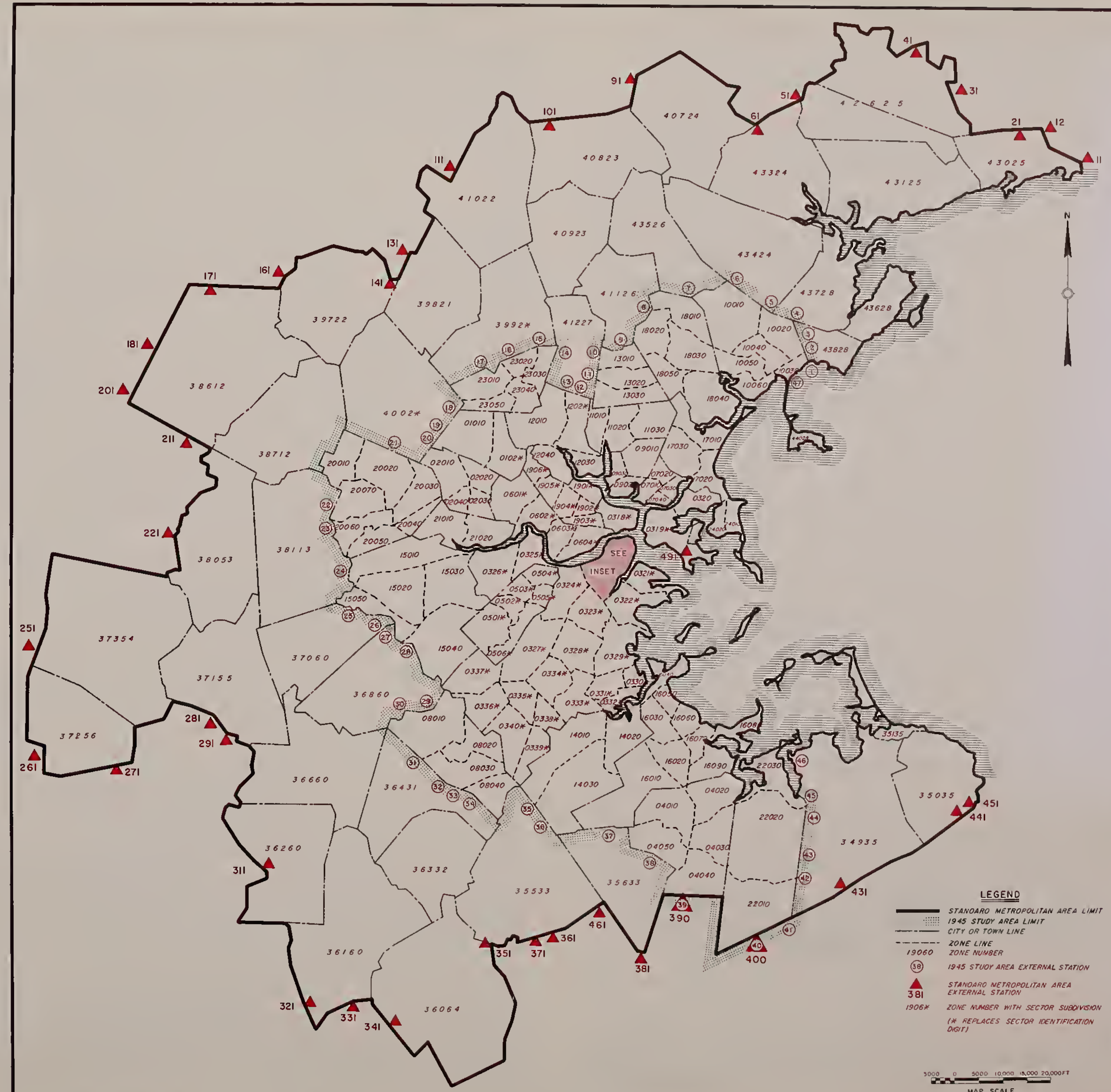


Exhibit T-5

ZONE AND STATION LOCATION MAP

Station Nodes

The external station nodes, representing the study area limits, serve as transmitting points for all trips from or to the study area. There are two such sets of station nodes, the first to represent the 1945 study area limits, and the second to represent the 1950 Standard Metropolitan Area limits, which comprise the limits of the Study Area. In the expressway assignments, the first set was retained in the spider network as route nodes.

Route Nodes

After the previous nodes were geographically located, an overlay plan of the existing arterial street system was prepared, and wherever these travel paths deviated significantly from those described by the original network, "Route Nodes" were introduced to represent such arterials as a further supplement to the spider network.

Dummy Nodes

In order to comply with efficient computer memory storage capacity, a node could be linked to a maximum of seven node neighbors. Whenever conditions created more than seven neighbors, a dummy node with the same location coordinates was introduced, thereby increasing the neighbor capacity of a node to twelve.

The initial coding began with the reduction of cities and towns shown in Exhibit T-4 into the zones of the 1945 Study Area, as shown in Exhibit T-5. The centroids of these areas were geographically located with respect to their centers of population and the Massachusetts grid coordinate system.

The various types of node described above were then connected by links in such a way as to produce a skeletonized pattern of travel paths in the basic 1945 Study Area spider network. Thus a given link of the spider network was so planned as to represent the equivalent of a combination of streets whereon vehicles could travel between one center of generation or attraction and another.

Exhibit T-6

EXPRESSWAY NETS CODED FOR ELECTRONIC COMPUTATION

For the design year 1975, the area coded into the street net was expanded to the limits of the Study Area.

THE EXPRESSWAY NETWORKS

The networks representing the existing and proposed expressways for the various years were prepared on the "overlay" principle using the basic spider network of 1945 as a datum. The links of these networks, unlike the street net, were prepared in one-to-one correspondence with the physical sections of the expressway so that it would be possible to determine the ramp volumes, as well as the mainline volumes as developed by the model generation and assignment program. A special code was devised so that a five-digit node identification number indicates the expressway serial number, the interchange number, the traffic direction on the expressway and whether the node is on the expressway or at the street-end of a ramp.

Existing Expressways

The work of coding the existing expressways followed the same procedure as that for the basic spider network. The expressways existing in 1955 were prepared as an addition to the basic 1945 net, and the resulting net was then used for computations referring to 1955. Representation of the expressway construction which took place between 1955 and 1959 was then added to this network in the same manner to yield a net for computations referring to 1959. The existing expressways, as shown in Exhibit T-6, consist of the Northeast Expressway to the Revere Airport Interchange, the East Boston Expressway to McClellan Highway, the Central Artery and its extension to Massachusetts Avenue, the Southeast Expressway to Hingham, the Fall River Expressway, the Massachusetts Turnpike from Route 128 westward, Route 3 from Route 128 to the northwest, the Northern Expressway, and Route 128.

Proposed Expressways

In like manner the proposed expressways were prepared for computer input; a total of three different network configurations were coded and used in computer traffic assignments. Common to all three, as shown in Exhibit T-6, are the proposed Route I-95 in the northeast quadrant with its connectors to the Northeast Expressway, to the East Boston Expressway, and to Beverly and Salem; Route I-95 in the southwest quadrant south of Route 128, and the Southwest Expressway northward to Neponset Valley Parkway; the Massachusetts Turnpike Extension (Western Expressway) between the Inner Belt and the Boston-Newton line; the Northwest Expressway from the Inner Belt to Route 2 and its connection with the existing Northern Expressway; the extension of the Northern Expressway to the Inner Belt; and Route 2 from the Northwest Expressway to the west.

For the expressways which are the subject of this Study, it was recognized that most of the alternative locations which were studied would provide essentially similar traffic service to the areas through which they pass. Therefore, those alternatives which represent the greatest variations in alignment were chosen for inclusion in the computer-assignment networks so that assignable volumes would be available from one or another of the computer outputs, or from interpolations between outputs, for any of the alignments.

Network One thus included additionally the Inner Belt along the "Ruggles Street route" in Boston and the "Brookline Street route" in Cambridge; the Southwest Expressway from the Inner Belt to Neponset Valley Parkway by a westerly route; the Western Expressway from Route 128 to the Boston-Newton line by the "railroad route"; and Route 3 from Route 128 to an interchange with Route 2 at the Arlington-Lexington line.

Network Two included, in addition to those expressways common to all nets, the Inner Belt along the "Tremont Street route" in Boston and the "River Street route" in Cambridge; the Southwest Expressway from the Inner Belt to Neponset Valley Parkway by an easterly route; the Western Expressway from Route 128 to the Boston-Newton line by the "river route"; and Route 3 from Route 128 to an interchange with Alewife Brook Parkway.

Network Three included the Massachusetts Turnpike Extension in its entirety from Route 128 to the Central Artery in the vicinity of South Station; in all other respects this network was identical with Network One.

SELECTION OF REPRESENTATIVE SPEEDS

LINK SPEEDS

The generation and assignment program evaluates the travel time between each of the connected nodes of the spider network representing the road system of the Boston Metropolitan Area. This evaluation is based upon the computed straight-line link distances and upon a speed code number assigned to each link. The speed code consists of one of the digits 1 through 9, each of which represents a speed in miles per hour, in five-mile-per-hour increments. The first step in the process of assigning a speed code number to a link was to compare the link geographically with the street or streets which it represents, and to take into account the difference in travel distance between the link and the streets. The speeds were then based upon total elapsed time from point to point including normal delays and stops.

In assigning speeds, reference was made to the following sources of field test data:

a. Travel time studies on Boston streets, arterial highways, and Route 128 made by the Joint Highway Research Project of M.I.T. and the Massachusetts Department of Public Works.[11,12] The data for these studies was collected by the floating-car method and stopwatch-timed observations. The study was conducted on selected major streets of downtown Boston and outlying areas.

b. M.I.T. Bachelor of Science theses on highway travel conditions and travel times between 1948 and 1958.[31,33,42]

c. Speed studies made for the Metropolitan District Commission on M.D.C. parkways and connecting arterial streets by their consultants, Bruce Campbell & Associates of Boston. The data for these studies was collected by two methods. In one study speed-delay data was obtained by use of an instrumented floating car, while in another a radar speed meter was used to determine 85-percentile speeds at selected locations.

d. Current speed runs on arterial highways by the consultant's staff, used to verify the continuing applicability of the above-cited references. Average running time observations were made over a period of weeks on selected

major arterial and expressway routes.

The speeds used for the spider nets represent considered judgment on average daily speed in both directions consistent with known average daily traffic (ADT). Speeds were first assigned to the spider network representing the street pattern in 1945 without expressways. In assigning speeds a critical point-to-point examination was first made of the spider network with reference to the actual conditions of the highway system. Speeds were then assigned to the links according to the speed characteristics of the actual highways represented. Since the spider network links used in the computations are straight between points and the road net usually is not, allowance was made to take this difference into account, using the above-cited references and the Detroit Study airline-road distance curves[55] as guides. The speeds between pairs of points not representing an arterial highway were obtained by examining the map to find a practical route and the characteristics thereof between these points. The speed was then assigned according to the characteristics of this route.

In the determination, speeds were rounded off to 5 miles per hour (mph) increments. In general, the street network speeds assigned were 10 mph in the Central Business District, 15 mph in the outer fringe of this district, 20 mph in the inner suburbs, and 25 mph or over in the outer suburbs, depending upon local conditions and type of road.

These speeds were then revised as necessary to the years 1955 and 1959, for use with the 1955 and 1959 spider nets, and speeds for the expressways existing in these years were added. Speeds were then determined for the expressway nets for 1975, and the street speeds based on 1959 conditions were applied to the 1975 network without change. Although it is possible that the building of the expressway system will cause an increase in speed on some streets due to reduction in traffic volume, experience has shown that such benefits are usually temporary and tend to disappear as local traffic builds up.

Speeds were applied to the 1975 expressway nets giving consideration to actual speeds on sections completed as of 1959, and on other existing expressways similar in design to proposed sections. The expressway speeds adopted were 30 mph on the Inner Belt, 40 mph on radials for the first four miles out from the Inner Belt, and 50 mph for sections beyond four miles. Ramp speeds were set at between 15 and 25 mph.

The speeds assigned to the Mystic River Bridge and Sumner Tunnel, both toll facilities, were first assigned on the above-noted bases, and subsequently reduced to reflect the well-known diminution in desire to use such facilities due to the existence of tolls.

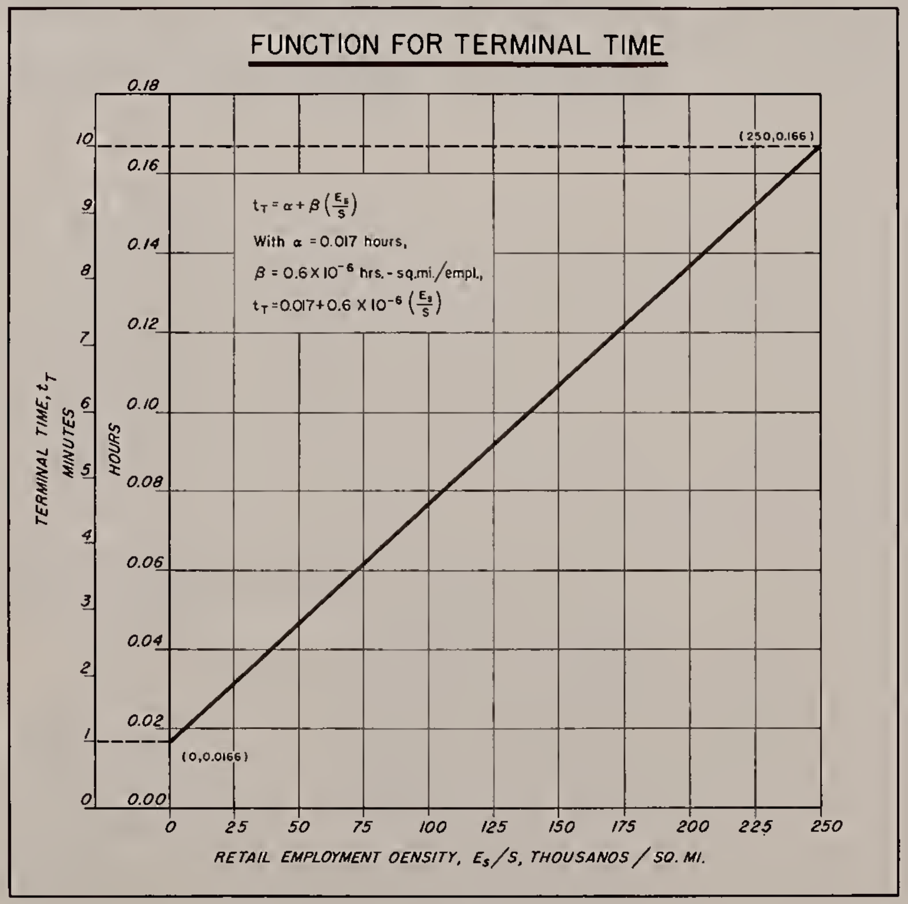


Exhibit T-7

TERMINAL TIME

The various possible methods of introducing terminal time per trip were investigated. Terminal time is defined as the amount of time required for a vehicle to get on the road at the start of a trip, and to find a place to park at the end of the trip. On the basis of these investigations terminal times were added to the previously computed sum of link-times to arrive at a total travel time:

$$\Sigma t = t_{ij} + t_{Ti} + t_{Tj},$$

where Σt = total travel time,
t_{ij} = sum of link-times for path, or path-time,
t_{Ti} = terminal time for origin (Zone i),
and t_{Tj} = terminal time for destination (Zone j).

On a rational basis terminal time can be expected to vary directly with retail employment density with acceptable correlation. For the suburbs, with a low retail employment density, the terminal time might rationally be of the order of magnitude of one minute, while in the most heavily commercialized zone of downtown Boston, with a density of roughly 250,000 retail employees per square mile, terminal time might conceivably be of the order of magnitude of ten minutes. These boundary conditions were used to establish a linear variation in terminal time of the form:

$$t_T = \alpha + \beta \frac{E_S}{S}$$

where t_T = terminal time in zone specified,
α, β = fitting parameters,
E_S = retail employment,
and S = zone area, square miles.

The Greek-letter values may then be varied to establish the validity of the relationship and to aid in arriving at a best fit of computed to surveyed volumes. In Exhibit T-7 the values $\alpha = 1$ minute in a residential zone (no employees) and $\beta = 0.000006$, to yield 10 minutes at 250,000 retail employees per square mile, have been substituted in the above equation and the resulting function plotted. These values were determined by the subsequent use of computer parameter-set runs to yield adequate results and were therefore used in applications of the gravity model equation.

SOCIOLOGICAL INPUT DATA

GRAVITY MODEL INPUT REQUIREMENTS

In the gravity model theoretical study, the population factor was hypothesized as the major multiplier of car ownership; a modifying multiplier having low correlation with population was also

specified as a term of the generation section of the gravity model equation. Similarly, in the attraction section of the equation total employment was propounded as the major factor, to be modified by some other non-correlating factor. The nature of the cor-ownership factor to be used, as well os the types of modifiers, were then determined.

Simultaneously with the preparation of network input dato, the relationship between the various available types of sociological data were therefore studied. These studies were conducted by plotting, on o town-total basis, one factor against another and visually noting the amount of correlation or lack thereof. These plots included:

a. Vehicle registration vs. population.
b. Vehicle registration vs. dwelling units.
c. Vehicles per dwelling unit vs. labor force.
d. Population vs. labor force.
e. Population density per square mile vs. labor force.
f. Population density per square mile vs. dwelling units.
g. Population density per square mile vs. vehicle density per square mile.
h. Total employment vs. labor force.
i. Totol employment vs. retail employment.
j. Total employment vs. retail employment density per square mile.

These plots led to the following visual observations:

a. A very high correlation exists between population and labor force per town.
b. A low correlotion appears to exist between population density ond labor force.
c. A low correlation exists between total employment and retail employment.
d. A low correlation exists between vehicles per dwelling unit and labor force.

On the basis of these observations, it was postulated first that figures for vehicles per dwelling unit would serve as a measure of car ownership. Second, it was found to be unnecessary to deol with both population and labor force, due to the high correlation between them; the population factor was therefore chosen as being a more general statistic than labor force. Third, population density should be used as the modifying term of the generation section of the equation, inasmuch as this statistic would reflect the home-based non-work trips. Fourth, retail employment density should be used as the modifying term of the attraction section of the equation, as representing attraction of home-based shopping and commercial trips. These choices were introduced into the gravity model equation, and sociological data were compiled for computer input on these boses.

With the introduction of the modifying factors, the grovity model become:

$$T_{ij} = K\left[\frac{V_i}{U_i}P_i + A\frac{P_i}{S_i}\right]\left[\frac{\left(\dfrac{E_j + B\frac{E_{sj}}{S_j}}{f(\Sigma t)}\right)}{\sum\limits_j\left(\dfrac{E_j + B\frac{E_{sj}}{S_j}}{f(\Sigma t)}\right)}\right]$$

where T_{ij} = trip transfer volume generated at zone i and attracted to zone j,
V_i = vehicle registration of zone i,
U_i = dwelling units of zone i,
P_i = population of zone i,
S_i = land area of zone i,
E_j = total employment of zone j,
E_{sj} = retail employment of zone j,
S_j = land area of zone j,
K,A,B = fitting parameters,
$f(\Sigma t)$ = function of total path time
$= \gamma + \partial(\Sigma t) + \epsilon(\Sigma t)^2$

and $\Sigma t = t_{ij} + t_{Ti} + t_{Tj}$

In order to apply social and economic data, historic or forecast, to the gravity model, the data had to be mode to correspond to the 261 traffic-generating nodes of the model. The zones to be represented by nodes must necessarily be small so that they con be represented by a single point. It can be stated thot as the bosic zone upon which the troffic forecosts ore bosed becomes lorger, greater troffic distortions ore introduced through its representation as o single point. However, in any sociological forecost such as population or employment, it is generolly ogreed that greoter overall occurocy con be obtained at o lorge scole such as for a metropolitan area, than at a smaller scole such as for an individual town within o metropoliton oreo. Nevertheless such o breakdown is necessary in order to meet the input requirements of the mothematical model. In order to do this on o rotionol basis, reasonoble criteria were developed os discussed below.

EMPLOYMENT

As discussed above, the total employment in a given zone was used as one of the indices of the attractive power which that zone would exert on trips originoting in neighboring (or the same) zones.

Primary Sources.

Both the Massachusetts Division of Employment Security and the U. S. Deportment of Labor keep records of employment by towns in Massachusetts. In neither cose do these statistics cover everyone employed in the State. The employees not included generally foll into the categories of governmentol, institutionol, educotional, railrood, charitable and professional groups. Thus for any given year, a so-called "covered" employment figure can be obtained by towns in the Standard Metropoliton Area. Less complete information is ovailable on the remoining, or "non-covered," employment. The Division of Employment Security does make an estimote of totol employment for a group of 41 towns in the Boston Metropoliton Area. While this estimate includes all persons employed, it is not on an individual town bosis. Thus it wos necessary to supplement the covered employment for eoch town with known concentrations of non-covered employment such os the Boston Naval Ship Yard, Massochusetts Generol Hospitol, Harvard University and other institutions. In oddition, some portion of the difference between totol estimoted employment ond covered or known employment hod to be odded to eoch town's employment figure.

Distribution of Town Employment Into Zones.

After estimates of employment by towns for the present and past years were completed they were further subdivided to correspond to the basic origin and destination zones. This breakdown of employment was made on the basis of the acres of business and industrial land use in the various zones of a town. Within any one town, total employment was distributed among the zones of that town in the same proportion as the acres devoted to business and industrial uses.

Distribution: City of Boston.

The above procedure provided an adequate basis for distribution of employment in the towns surrounding Boston, but it was clear that this basis should be refined for the City of Boston. This is due to the intensity of land development, especially in the Central Business District, where the amount of land area devoted to business and industrial activities probably does not give a reliable index to the amount of employment, so that a more detailed approach was decided upon. Expedited by the Greater Boston Economic Study Committee, a report by the Massachusetts Division of Employment Security for the City of Boston on employment data was obtained. This report gave an activity code number, firm name and address, and number of employees of all firms which were covered during 1957. From this information, covered employment by zones was obtained directly with the aid of a city street atlas.

There is no reliable land-use inventory map of the Metropolitan Area for 1945. The present land use was therefore used as a guide to the distribution of 1945 and 1955 employment among zones. This tended to introduce a degree of insensitivity into comparisons between 1945 and 1957 employment by zones. However, important changes in land development would be reflected by the covered-employment figure for the town, and the insensitivity would apply only to the distribution of this figure among the zones within the town.

Covered employment statistics were available for each year through 1958, but were not at the time of analysis available for 1959; the two-year trend 1955–1957 was therefore extended to 1959 to obtain the statistical information for that year's input.

Total Employment, 1975.

Estimates were made of total 1975 employment in various areas of the metropolitan region, as discussed in Part IV of this Study, and were then distributed among the individual towns. A further distribution of net employment gain or loss for individual towns was made among the zones within the towns. This further distribution was based on previous data related to available industrial and commercial sites, the demand for such development in the particular area, existing zoning regulations, and estimated redevelopment sites and rates of development.

Retail Employment.

Retail employment density was used as the most indicative and most readily obtainable index of the magnitude of retail commercial activity and, therefore, attraction power for those trips whose purpose is shopping. Another possible index considered was retail sales. However, this would be subject to certain limitations as an indication of attraction power due to the varying nature of the product sold, e.g., a jewelry store versus a stationery store. The volume of retail sales has the additional disadvantage of being difficult to obtain accurately.

Retail employment statistics were compiled, in much the same manner as were total employment statistics, from the Division of Employment Security town-level figures for 1945, 1955 and 1957. As in total employment, the 1955–57 trend was projected to obtain the 1959 figure. The retail employment total for each town was distributed among the various zones within the town in direct proportion to the land area which is devoted to commercial activities.

Retail employment for the design year 1975 was established by towns, and the net difference, 1959 to 1975, was distributed according to the land development treatment as used with total employment.

DWELLING UNITS

Primary Sources.

The U. S. Census lists dwelling units in its decennial census reports, and these data have been used for reference purposes. For the intervening years, the various electric power companies' and the New England Telephone and Telegraph Company's yearly estimates of the number of households or residential customers in their service areas were used. These estimates generally take into account new construction, conversions, and demolitions. The electric companies are required by law to report annually to the Massachusetts Department of Public Utilities the number of residential customers which they serve. The number of residential customers approximates the number of dwelling units. All of the above source material was analyzed in the course of this Study. The electric company data was used in general for the municipalities surrounding Boston. On the other hand, the telephone exchange data gave a better breakdown within the City of Boston, but was subject to certain necessary adjustments since the telephone exchange boundaries do not correspond exactly to the origin and destination zones. The exact locations of exchange boundaries were obtained so that the comparison of areas could be carefully made.

Distribution Into Zones.

The municipality totals for dwelling units were distributed among the zones in direct proportion to the population per zone. Although this procedure disregards any variations of family size which may exist within a single town, it was deemed entirely adequate for this type of distribution.

Dwelling Unit Projections, 1975.

The 1975 projections reflect both the existing inventory of dwelling units and the net increase or decrease in population. The ratio of population to dwelling units was calculated for each of the cities and towns for 1959. This factor was then applied to the net increase or decrease in population to determine the net increase or decrease in dwelling units. Thus the number of dwelling units in 1975 is given by:

$$DU_{75} = DU_{59} + \frac{Pop_{75} - Pop_{59}}{(Pop/DU)_{59}}$$

For the twenty-four cities and towns in the 1945 study area, the ratio for each town was applied to the population change for that town. However, for the forty-one additional towns included

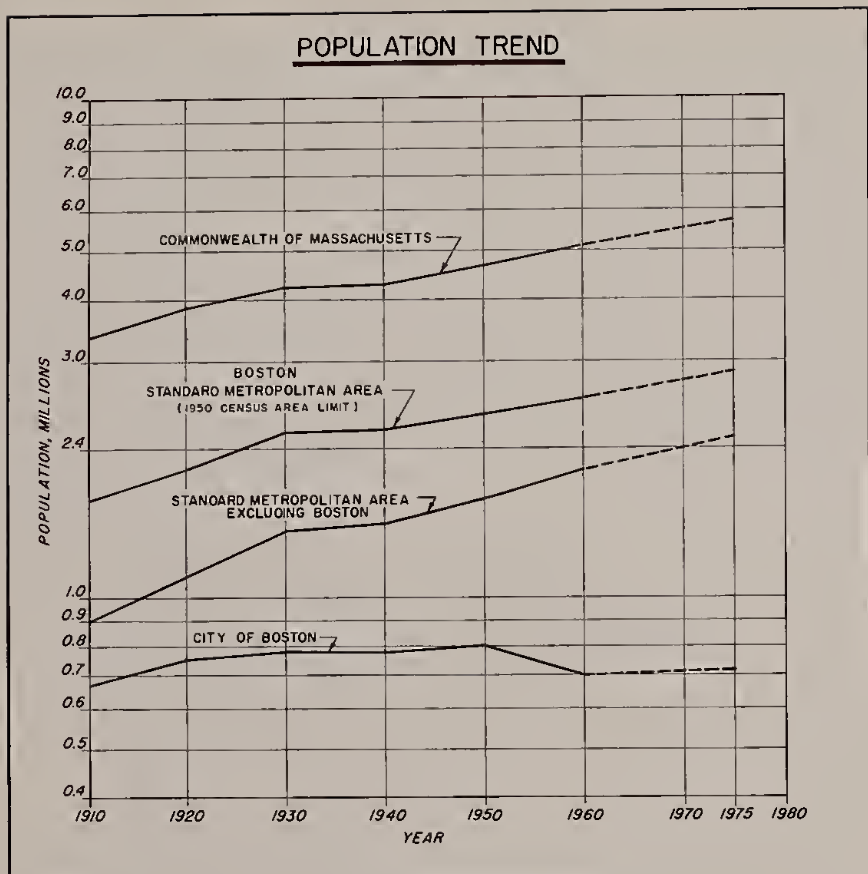


Exhibit T-8

in the Standard Metropolitan Area, the average persons-per-dwelling-unit ratio was used throughout, since variations did not appear significant.

POPULATION

The population movement and expansion within the Boston Metropolitan Area, based on the Federal Census Reports of 1910 through 1960, with projections to 1975, is illustrated in Exhibit T-8. Massachusetts census data was not used therein because the two census reports, Federal and Commonwealth, are taken on different bases; the Federal census includes students and military personnel wherever they are found, while the Massachusetts census includes only those regularly rather than temporarily resident. The limits of the Standard Metropolitan Area have in the past changed with each Federal census, and for this Study the 1950 Federal census limit of 65 cities and towns has been used.

Using the 1940 census year as a base, the percentage change over the years is shown in Exhibit T-9 for the Commonwealth of Massachusetts, the 1950 Standard Metropolitan Area of 65 cities and towns, the Standard Metropolitan Area excluding Boston, and the City of Boston. It is apparent that the area surrounding the City of Boston has grown at a much higher rate than the Commonwealth as a whole. The Standard Metropolitan

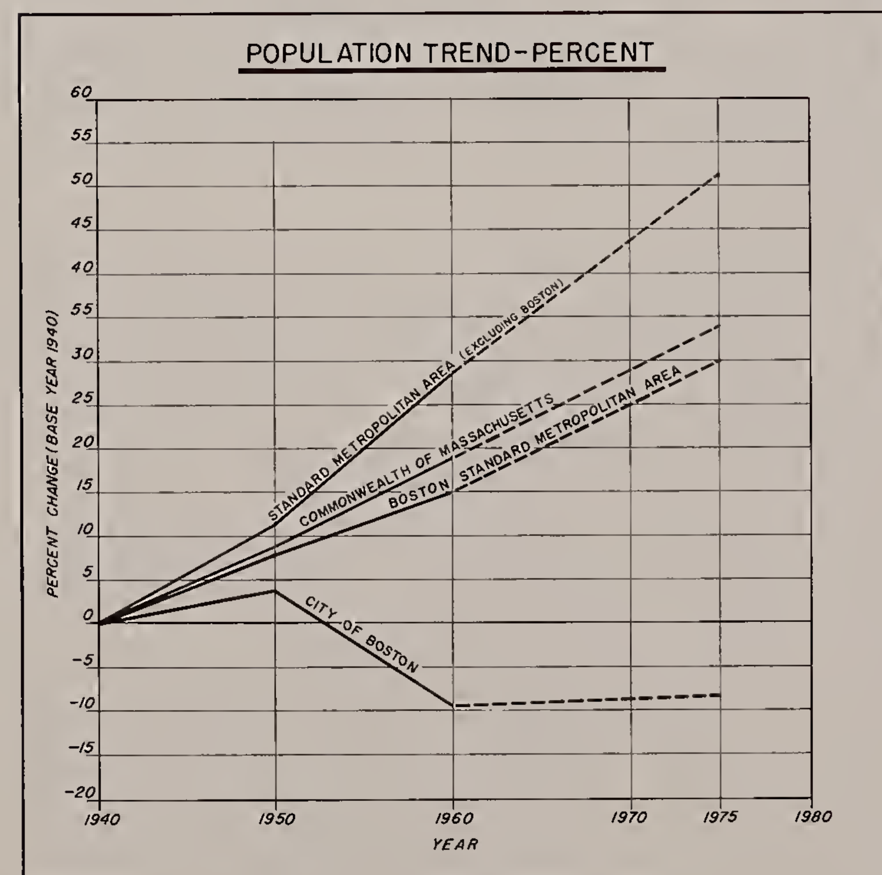


Exhibit T-9

Area excluding Boston has increased by 29.1% from 1940 to 1960 and for the time period 1940 to 1975 there is an expected increase of 51.1%. The Standard Metropolitan Area with Boston included has shown a 15.4% change for the period 1940–1960 and an expected increase of 30.2% for the period 1940–1975. The Commonwealth as a whole increased 19.3% for the years 1940–1960 and has an expected increase for 1940–1975 of 33.7%. While the other areas have been increasing, the City of Boston has fluctuated with an increase from 1940 to 1950 of 4.0%, but a decrease from 1950 to 1960 of 13.4%, so that the overall change from 1940 to 1960 has been a decrease of 9.5%, and the expected change from 1940 to 1975 is a decrease of 7.9%.

Population estimates for computer input were prepared for the years 1945, 1955, 1959, and 1975 for all municipalities, and the basic distribution by zones was made for 1955. The estimates for the other years, except 1975, were proportioned among the zones on the basis of the 1955 population distributions. The net increases or decreases in town or city populations between 1959 and 1975 were assigned to various zones on the basis of available land, accessibility, existing zoning, and probable redevelopment sites. In some cases a redistribution of population within a city or town was judged probable, so that the net increase or decrease, 1959 to 1975, was the result of a population decline in one portion thereof and a population increase in another section of the same area. This is especially true in the case of Boston where the central city population is already declining in relation to areas nearer to the periphery of the city.

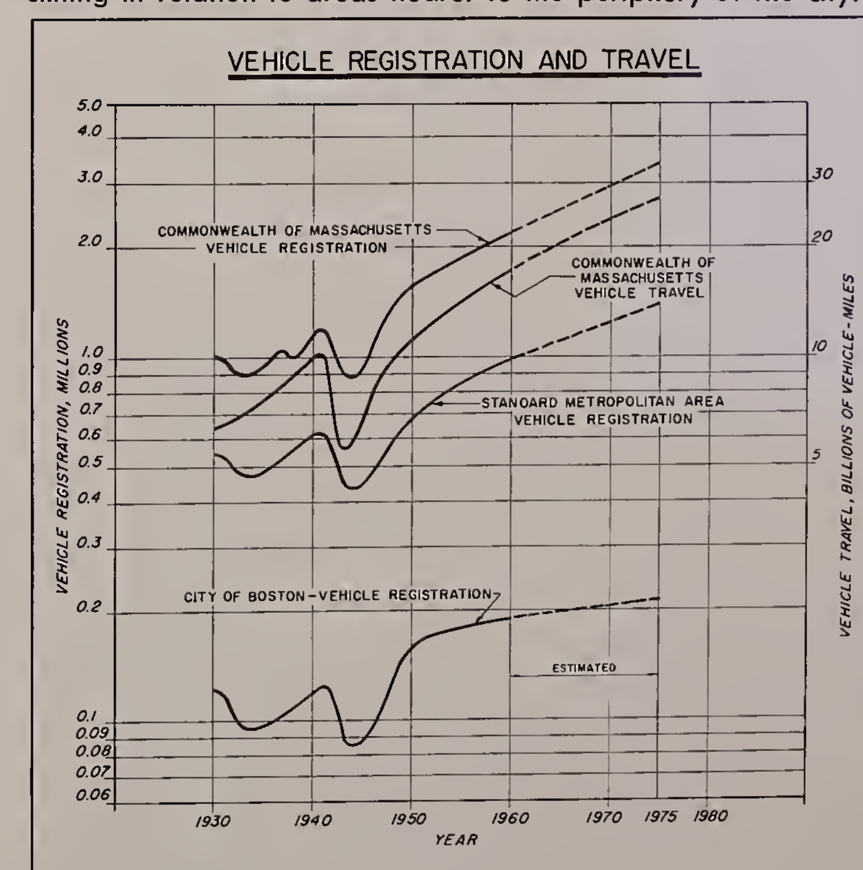


Exhibit T-10

MOTOR VEHICLE REGISTRATION

Primary Sources.

Vehicle registration and travel trends are illustrated in Exhibit T-10. The two sources of information relating to motor vehicle statistics were the Bureau of Excise Tax of the Commonwealth Department of Corporations and Taxation, which lists the number of motor vehicles and trailers on which the excise tax is levied, and the *New England Auto List*, a private organization which lists yearly passenger car and truck registration by towns. The excise tax listing results in a higher figure because trailers are included with motor vehicles, and also because of surrendered plates and re-registration duplications. The *New England Auto List* was used as the source of data for the years 1955 through 1958. The 1955-1958 trend figures extended to 1959 were also used. Statistics of the Bureau of Excise Tax were used for the year 1945.

Distribution into Zones.

The total vehicles per municipality were distributed into the city or town component zones in proportion to the resident population in those zones. Within the City of Boston, the *New England Auto List* records figures for Brighton, Charlestown, Dorchester, East Boston, etc.; within these classifications, total vehicles were distributed in direct proportion to the population.

1975 Motor Vehicle Projections.

In projecting the motor vehicle registration, both the area differences in vehicle ownership and the changing ratio of persons to vehicles were taken into consideration. The persons-per-vehicle ratio for each of the cities or towns was calculated and the results were grouped according to geographic location and similarity of economic characteristics, of which vehicle ownership is one. The overall persons-per-vehicle ratio of each of the groups of municipalities was then calculated. The next step was to plot the persons-per-vehicle ratio for the original 1945 study area at several points over the last fifteen years in order to determine the rate at which vehicle ownership has been increasing with time. Present trends were extended to 1975 and compared with trends of other metropolitan areas, as illustrated in Exhibit T-11. The persons-per-vehicle ratio as projected by this method was found to decrease between 1959 and 1975 by a factor of 1.22.

The 1975 population for each city or town and each zone was then related to two factors, the 1959 persons-per-vehicle ratio of the particular group of cities and towns to which it belongs, and a constant factor representing the projected average

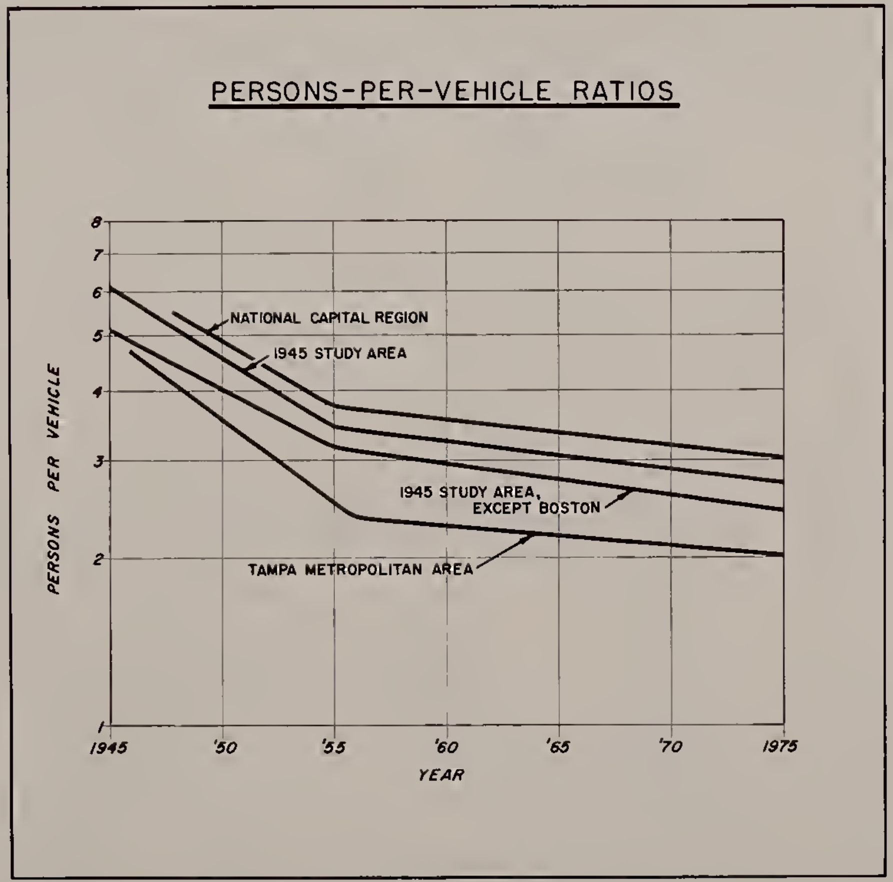


Exhibit T-11

change in the persons-per-vehicle ratio between 1959 and 1975. Thus the number of motor vehicles in 1975 is given as:

$$MV_{75} = Pop_{75}\left(\frac{1.22}{(Pers/Veh)_{59}}\right)$$

COMPUTER PROGRAMMING

The preparation of computer programs was carried on concomitantly with the previously discussed work. As illustrated in Exhibit T-12, and described below, seven major programs were prepared, primarily in IBM FORTRAN language, three of which included optional sub-programs. Also illustrated is the generalized procedure of computer operation necessary to yield any given output desired.

LINK-DISTANCE AND LINK-TIME PROGRAM

This program computes, from the spider network input, the distance between neighbor nodes, or link-distance, on the basis of the coordinates provided, and the travel time between nodes, or link-time, on the basis of speed codes provided.

Ramp Impedance and Toll Delay Sub-Program.

This program was prepared in order to add to expressway ramp link-times one of four assignable constant times in thousandths of an hour, to represent the effect of street congestion on ramp operation. It may also be used to assign additional time to links representing toll facilities, given constants for cents per minute and cents per mile which are relevant, as follows:

$$t_T = t_L + L\left(\frac{C_D}{C_T}\right)$$

where t_T = total link-time, minutes,

t_L = link-time computed from coordinates, minutes,

L = link-distance computed from coordinates, miles,

C_D = distance cost of using toll facility, or toll charges, in cents per mile,

and C_T = time cost of using toll facility, or payment acceptable to operator per minute of time saved, in cents per minute.

Although of considerable value in many applications, it was ultimately found inadvisable to use this sub-program, since the basis for its use was in this case in direct conflict with the concept of capacity-restricted assignments as applied to the Massachusetts Turnpike.

MINIMUM PATH TIME (TREE-BUILDING) PROGRAM

This program computes from the results of the link-time program, the minimum-time path from each volume-producing node to all other nodes. It is called "tree-building" because a plot of the minimum-time paths from any one node to all other nodes has the appearance of a tree.

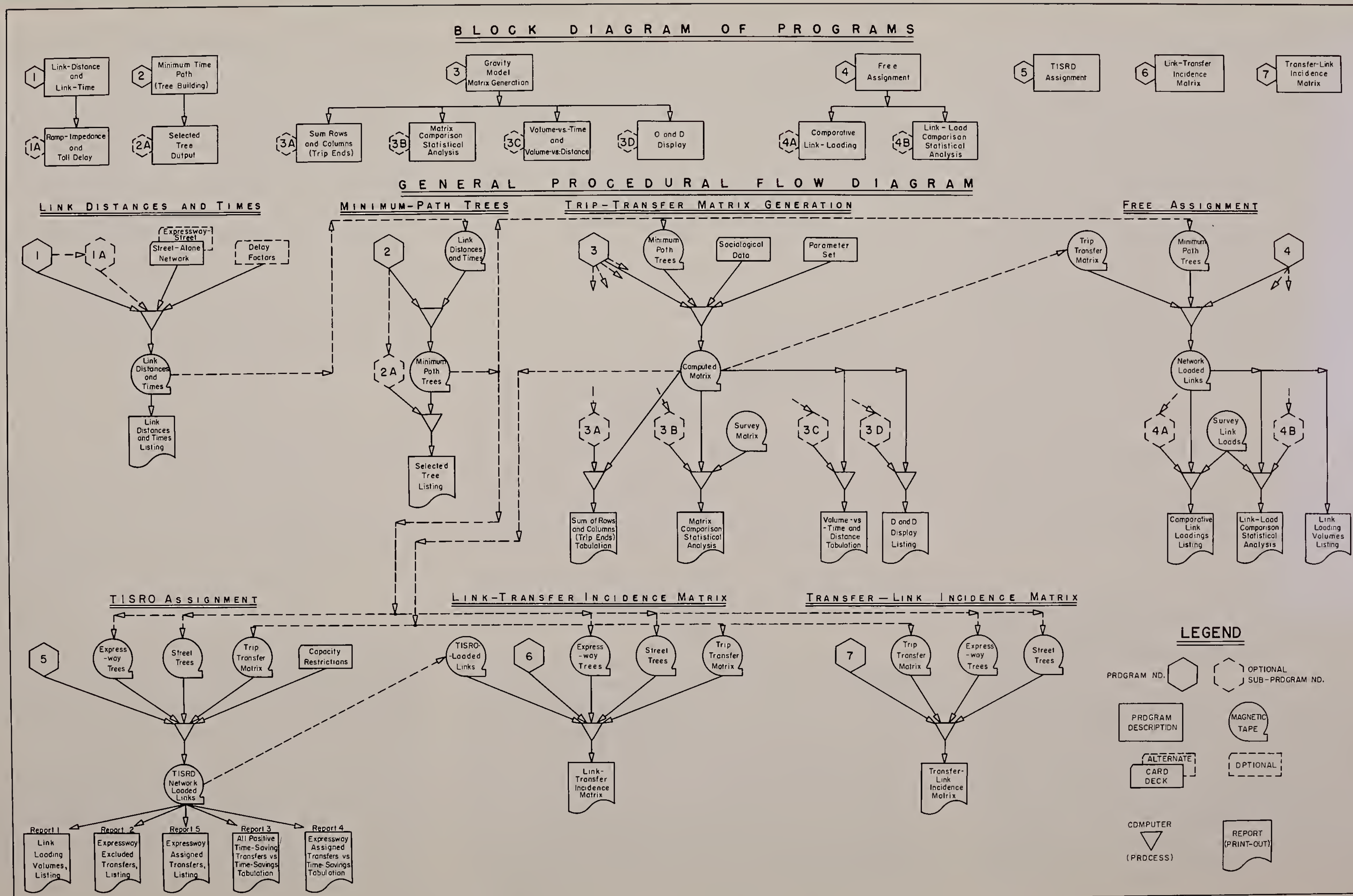

BLOCK DIAGRAM OF PROGRAMS
1 Link-Distance and Link-Time
1A Ramp-Impedance and Toll Delay
2 Minimum Time Path (Tree Building)
2A Selected Tree Output
3 Gravity Model Matrix Generation
3A Sum Rows and Columns (Trip Ends)
3B Matrix Comparison Statistical Analysis
3C Volume-vs.-Time and Volume-vs.-Distance
3D O and D Display
4 Free Assignment
4A Comparative Link-Loading
4B Link-Load Comparison Statistical Analysis
5 TISRO Assignment
6 Link-Transfer Incidence Matrix
7 Transfer-Link Incidence Matrix
GENERAL PROCEDURAL FLOW DIAGRAM
LINK DISTANCES AND TIMES
Expressway-Street
Street-Alone Network
Delay Factors
Link Distances and Times
Link Distances and Times Listing
MINIMUM-PATH TREES
Link Distances and Times
Minimum Path Trees
Selected Tree Listing
TRIP-TRANSFER MATRIX GENERATION
Minimum Path Trees
Sociological Data
Parameter Set
Computed Matrix
Survey Matrix
Sum of Rows and Columns (Trip Ends) Tabulation
Matrix Comparison Statistical Analysis
Volume-vs-Time and Distance Tabulation
D and D Display Listing
FREE ASSIGNMENT
Trip Transfer Matrix
Minimum Path Trees
Network Loaded Links
Survey Link Loads
Comparative Link Loadings Listing
Link-Load Comparison Statistical Analysis
Link Loading Volumes Listing
TISRO ASSIGNMENT
Express-way Trees
Street Trees
Trip Transfer Matrix
Capacity Restrictions
TISRO Network Loaded Links
Report 1 Link Loading Volumes, Listing
Report 2 Expressway Excluded Transfers, Listing
Report 5 Expressway Assigned Transfers, Listing
Report 3 All Positive Time-Saving Transfers vs Time-Savings Tabulation
Report 4 Expressway Assigned Transfers vs Time-Savings Tabulation
LINK-TRANSFER INCIDENCE MATRIX
TISRO-Loaded Links
Express-way Trees
Street Trees
Trip Transfer Matrix
Link-Transfer Incidence Matrix
TRANSFER—LINK INCIDENCE MATRIX
Trip Transfer Matrix
Express-way Trees
Street Trees
Transfer-Link Incidence Matrix
LEGEND
PROGRAM NO.
OPTIONAL SUB-PROGRAM NO.
PROGRAM DESCRIPTION
MAGNETIC TAPE
ALTERNATE
CARD DECK
OPTIONAL
COMPUTER (PROCESS)
REPORT (PRINT-OUT)

Exhibit T-12

Selected Tree Output Sub-Program.

This program prepares a print-out of a single tree, which may then be plotted for analytical use. Any number of such trees may thus be prepared.

GRAVITY-MODEL PROGRAM

This program computes the amount of traffic generated at each volume-producing node on the basis of the sociological input data, and further computes the distribution of this traffic on the basis of this data and the total time between zones, using the minimum-time paths of the tree-building program as a base; the result is a complete rectangular trip transfer matrix on magnetic tape.

Sum of Rows and Columns (Trip-Ends) Sub-Program.

This sub-program reports the sum of each row and each column of the rectangular matrix prepared as above. The sum of a row added to the sum of the corresponding column then yields the total of all trip ends in the zone or sector stipulated.

Matrix Comparison Statistical Analysis Sub-Program.

This sub-program provides a statistical analysis of computed trip transfers as compared with surveyed trip transfers, and is used as a guide in determining the variable coefficient parameters of the model. Each computed transfer volume is compared with the corresponding surveyed transfer volume, and the difference determines the frequency range of differences into which that transfer is put. A threshold of volume of surveyed transfers to be compared may be imposed, and the report contains that threshold, the number of transfers above the threshold, the parameter set identification number, the values of the eight parameters for that set, the computed value of the correlation coefficient for that case, and the number of transfers in each frequency range of differences.

Volume-vs.-Time and Volume-vs.-Distance Sub-Program.

This program first sums the distances along each minimum path in each tree, and then tabulates from the trip transfer matrix the volume traveling a given time, not including terminal times, in increments of one-tenth hour, and a given distance in increments of two and one-half miles.

O. & D. Display Sub-Program.

This program yields a report of the trip transfer matrix prepared in the main program, and states the volumes of each trip transfer in that matrix.

FREE ASSIGNMENT PROGRAM

This program applies the results of the gravity-model program, the traffic movements between nodes, to the minimum-time paths (trees) previously obtained, resulting in a listing of all links of the network and the traffic volumes thereon.

Comparative Link-Loading Sub-Program.

This program prepares a report stating the link-loading of each link in the net from each of two different trip transfer matrices.

Link-Load Comparison Statistical Analysis Sub-Program.

This program is essentially similar to that used for matrix comparison as noted above, except that it compares the volume *assigned to each link* from the computed matrix with that from the surveyed matrix.

TISRO ASSIGNMENT PROGRAM

This program assigns traffic with greatest time-savings to an expressway only up to the designated capacity of that expressway. Traffic which desires to use that expressway, but has lesser potential time-saving than that which loads the expressway to capacity, is then assigned to the quickest alternate street path. The program yields five reports as follows:

Report 1: Link Loadings.

This report states the vehicle volume on each link due to transfers which use that link and have a positive time-saving using an expressway path, and also states the total volume assigned to that link.

Report 2: Expressway-Excluded Positive Time-Saving Transfers.

This report lists each positive time-saving transfer, and its volume, which is excluded from its expressway path and reassigned to a street path due to a capacity restriction on an expressway link and the existence of other transfers having a greater time-saving which use that link.

Report 3: All Positive Time-Saving Transfers vs. Time-Savings.

This report tabulates the sum of all trip transfer volumes having a stated range of potential time-saving via the expressway, in range increments of two-hundredths hours.

Report 4: Expressway-Assigned Transfers vs. Time-Savings.

This report tabulates in the same form as Report 3 the sum of all trip transfer volumes actually assigned to the expressway. In each range, the difference between the values shown in Reports 3 and 4 is thus the volume which has a potential time-saving via the expressway, but because of expressway capacity restrictions is assigned to the streets.

Report 5: Expressway-Assigned Positive Time-Saving Transfers.

This report lists each positive time-saving transfer, and its volume, which has a great enough time-saving to be assigned to its expressway path within the capacity restrictions on that path.

TRANSFER-LINK INCIDENCE MATRIX PROGRAM

This program prepares a report (Report "6") in which the links of the minimum-time path used by each trip transfer are presented in order of their use in the street path, and also in the expressway path, where such exists.

LINK-TRANSFER INCIDENCE MATRIX PROGRAM

This program prepares a report (Report "7") in which the load on each link of the net is presented in terms of the volume from each trip transfer using that link as a result of the TISRO assignment.

CARD-INPUT PREPARATION

Of extreme importance to the successful processing of the model is the accurate representation of the various networks and the accurate preparation of the card decks which serve as input to the computer. When it is considered that about 435,000 decimal digits were coded into these decks, and that the mis-coding

PREPARATION OF COMPUTER CARD-DECK INPUT

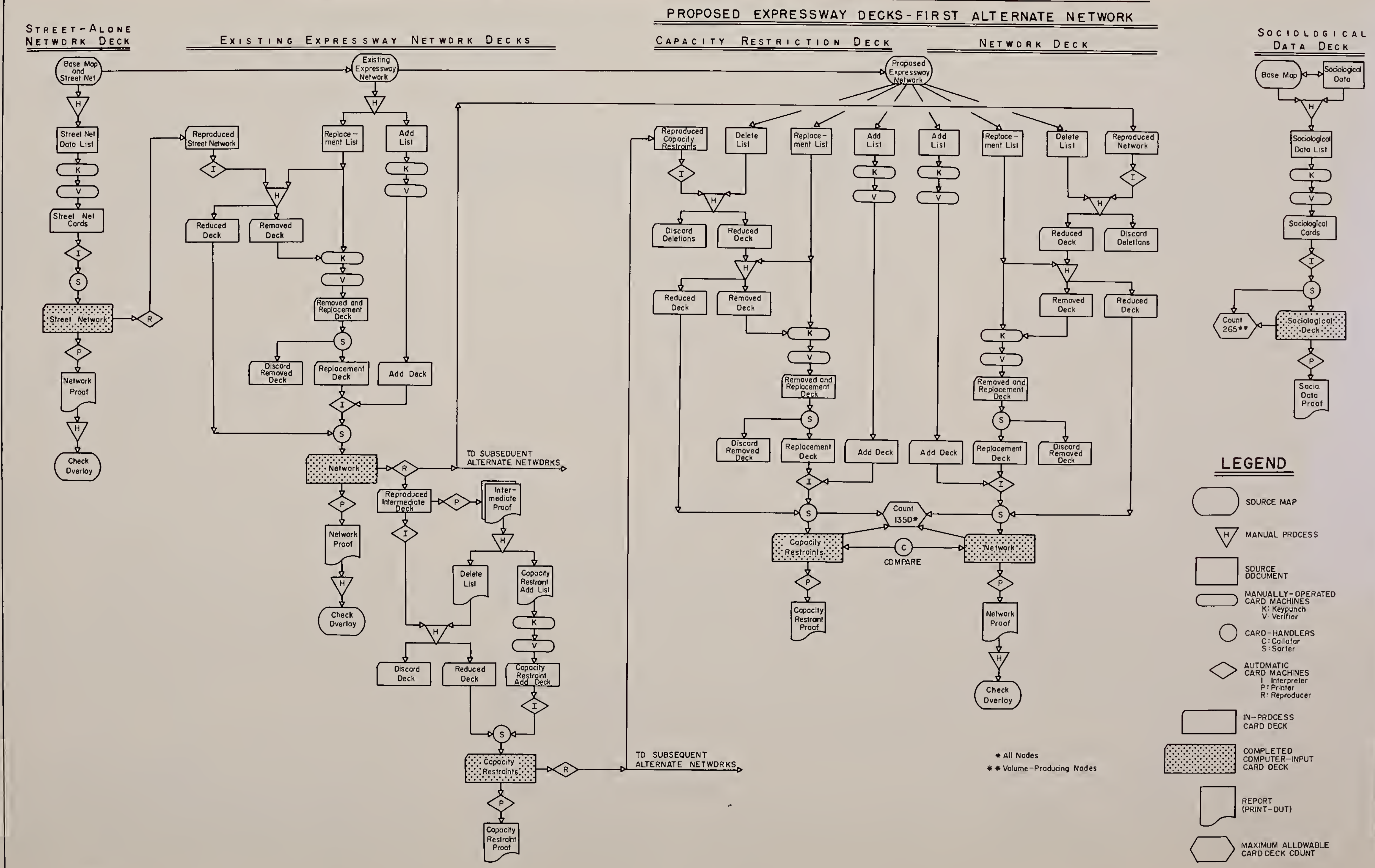


Exhibit T-13

of even one of these digits may completely invalidate the results of a computer run, it is evident that careful planning to minimize the possibility of error, and elaborate checking procedures to eliminate any residual error, are well justified.

The general flow diagram for preparation of card decks to be used as input to the computer is presented as Exhibit T-13. The zones, sectors, nodes, street-links and speeds are first plotted and coded on large-scale mylar reproductions of U. S. Geological Survey maps, from which the node codes, geographic coordinates, neighbor nodes and link speeds are listed. The lists are then key-punched on IBM cards, and key verified and sorted in order of entry node to yield a street-net-deck, which is then printed out. This print-out is then replotted on an overlay which is compared item-for-item with the original for elimination of error.

In order to preserve the accuracy of data thus prepared, the street-net-deck is then reproduced to serve as a basis for incorporation of the additional data required to represent the existing expressways. On overlays representing these expressways, each junction point of a ramp with a main-line link or street link is coded, and two lists are prepared. The first list enumerates all cards to be replaced in the reproduced deck with cards containing additional information; these cards are removed from the deck, the previously-verified information is duplicated, and the new data is added thereto. The second list enumerates cards that are completely new; these cards are key-punched and verified as were the original cards. The entire expanded deck is then printed out and the additions replotted on overlays for proofing. This process is essentially followed for each additional deck required as illustrated in the general flow diagram.

MODEL EVALUATION

DATA PROCESSING — PARAMETER DETERMINATION

The major programs having been proved out, and all 1945 input data having been assembled, work was commenced on the computer to arrive at suitable values of the variable coefficient parameters of the gravity-model equation. From the 1945 network input data, link-times were computed, after which the complete system of trees was computed for the 1945 network.

TABLE T-I
FITTING PARAMETER SET VALUES

Parameter Set	K	A	B	α	β	γ	δ	ϵ	Primary Use	Modifying Statistic
70	0.40	0.20	0.10	0.017	0.7×10^{-6}	0	0	1.0	1955	Population Density
90	0.60	0.10	0.10	0.017	0.7×10^{-6}	0	0	1.0	1959	Population Density
102	0.34	0.20	0.10	0.017	0.7×10^{-6}	0	0	1.0	1955, 1959	Employment Density
109	0.256	0.15	0.10	0.017	0.7×10^{-6}	0	0	1.0	1945	Employment Density
110	0.40	0.15	0.10	0.017	0.7×10^{-6}	0	0	1.0	1955, 1959	Employment Density
111	0.375	0.15	0.10	0.017	0.7×10^{-6}	0	0	1.0	1975	Employment Density

With these link-times and trees completed, the next step was to determine proper values of the parameter B, and the Greek-letter parameters, which may be described as determining the exponent of time, t. This work, since it refers only to the attraction portion of the gravity-model equation, was accomplished by estimating probable values of these parameters, and distributing input volumes transmitted from external stations to all zones on the basis of this portion of the equation and these estimates. The results were compared statistically with the known distribution of the 1945 station-to-zone survey data, and the parameters revised to bring the computed distribution into closer agreement with this known distribution. The function-of-time equation parameters were varied to represent exponents varying from 0 to 3 in increments of 0.5; it was found that the square represents an extremely good value of the t-exponent in this case, and that further refinement of the time-parameters would be impractical for the purposes of this Study, although interesting from a research viewpoint. It was also found that the best value of B is 0.1, i.e., with total employment as the major measure of attraction, the best fit to survey data is obtained by using one-tenth of retail employment density as the additive modifier.

Holding fixed the parameter values thus found, the remaining parameters were determined by computing trip transfer volumes using the complete gravity-model equation, and comparing these volumes statistically with the corresponding values of the complete 1945 survey trip transfer matrix. Initial values were estimated for the parameters K and A, and computations were made to arrive at the best-fit values of these parameters. It was thus found that parameter set 70, with values of K = 0.4 and A = 0.2 yielded a mean very close to zero in the statistical analysis. A list of all parameter sets here referred to is found in Table T-I.

The computer input for the 1955 computations having been prepared, the link-times for the 1955 spider network were next computed, and the trees were assembled. The 1955 volumes transmitted by external stations to the zones were then distributed using the attraction portion of the gravity model equation, and resulting trip transfers were compared with corresponding values of the 1955 survey data. All available 1955 surveyed trip transfer values were then compared as a minor check with computed values using the complete gravity model equation. As a result of these computations, values of K = 0.6 and A = 0.1 (parameter set 90) appeared to yield the best fit for 1955 data.

With the completion of computer input representing 1959 conditions, the 1959 link-times were computed and the trees assembled.

Since parameter sets 70 and 90, described above, showed the best fit of computed traffic to surveyed volumes, the 1955 spider network links were loaded with gravity-model generated traffic based on set 70, and the 1959 links were loaded based on set 90,

TABLE T-II
SCREEN-LINE ANALYSIS

Screen-Line	Year	Surveyed Volume	Parameter Set	Computed Volume	Per Cent Difference	Parameter Set	Computed Volume	Per Cent Difference	Parameter Set	Computed Volume	Per Cent Difference
Northern	1955	340,600	No. 70	408,764	+20.0%	No. 102	333,987	— 1.9%	No. 110	348,526	+2.3%
Northern	1959	510,660	No. 90	760,274	+48.8%	No. 102	509,319	— 0.3%	No. 110	499,384	−2.2%
Neponset River	1959	224,975	No. 90	322,358	+43.3%	No. 102	221,191	— 1.7%	No. 110	233,617	+3.8%
Downtown Cordon	1959	656,350	No. 90	1,125,126	+71.4%	No. 102	764,950	+16.5%	No. 110	710,741	+8.3%

for a cross-check comparison with screen-line data, as described below. At this time the 1945 surveyed data was loaded on the 1945 spider network, and also the 1955 surveyed data was loaded on the 1955 spider network. The sub-programs to yield trip transfer volumes and percentage volumes as functions of travel time and distance were also run to aid in obtaining better statistical fits of surveyed versus computed data.

The 1955 and 1959 screen-line checks on the basis of parameter sets 70 and 90, respectively, having shown greater than desirable percentage differences between surveyed and computed volumes (See Table T-II), the gravity model equation was re-examined in the light of the statistical analyses. It was judged that insufficient non-home based traffic was being generated by the gravity model; the parameter of total employment density was therefore substituted for population density as the modifier of population in the generation portion of the equation. The modifier thus reflects non-home based commercial trips rather than the home-based non-work trips previously used. The generation portion of the gravity-model equation thus became:

$$G_i = K\left(\frac{V_i}{U_i} P_i + A\frac{E_i}{S_i}\right)$$

Further statistical analysis yielded a better fit of 1945 computed data to 1945 survey data, although the volume-time analysis indicated a total volume generated that did not correspond with the total surveyed volume of trip transfers. Additional parameter sets were therefore used to determine values of K which would yield total volumes for 1945 and 1955 having better correspondence with total surveyed trip transfer volumes. Using parameter set 102, the 1955 net was loaded with 1955 computed volumes, and the 1959 net with 1959 computed volumes, and screen-line checks were made.

The 1975 input data for the computer having been prepared, the 1975 link-times were computed and the trees assembled. Using parameter set 102, the 1975 spider network was loaded with 1975 computed volumes, and also with 1959 computed volumes.

The 1945 spider network was also loaded with both 1945 surveyed traffic and 1945 traffic computed on the basis of a "K" which is a scaled-down equivalent to that used in set 102 for the years 1955 and 1959, because all growth curves indicate a departure from normal rate of growth for the war years, as may be noted in Exhibit T-8, and because a given group of sociological data would not accurately reflect the amount of traffic generated under the abnormal conditions of gasoline and tire shortages. It was therefore judged that an equivalent K should be used for the year 1945, rather than the same K that is used for years of "normal" growth.

Analysis of the loading of the 1945 net with both surveyed and computed volumes revealed a point in the machine program logic that required improvement. With the indicated revisions completed, new parameter sets were used in conjunction with 1945 surveyed data and computed traffic to determine the new best values of K and A. It was found that parameter set 109, with K = 0.256 and A = 0.15 yielded a higher correlation coefficent than had been attained previously, an acceptable position of the mean in the statistical analysis, and a total volume 0.14% higher than the surveyed volume. The equivalent K was found for 1955 and 1959 in parameter set 110, and the 1955 and 1959 links were loaded on the basis of this set. A check of the screen lines revealed that the volumes involved remained for the most part somewhat high, so that a minor adjustment was made to the value of K in parameter set 111 to reflect an overall decrease in volume of about 5% from that which would have resulted using set 110. The final gravity-model used for projection of the 1975 trip transfer matrix thereby became, including the values of parameter set 111:

$$T_{ij} = 0.375\left[\frac{V_i}{U_i} P_i + 0.15\frac{E_i}{S_i}\right]\left[\frac{\left(\dfrac{E_j + 0.10\dfrac{E_{sj}}{S_j}}{(\Sigma t)^2}\right)}{\sum_j\left(\dfrac{E_j + 0.10\dfrac{E_{sj}}{S_j}}{(\Sigma t)^2}\right)}\right]$$

and $\Sigma t = t_{ij} + \left(0.017 + 0.7\times10^{-6}\frac{E_{si}}{S_i}\right) + \left(0.017 + 0.7\times10^{-6}\frac{E_{sj}}{S_j}\right)$

with the terms defined as in the original equations.

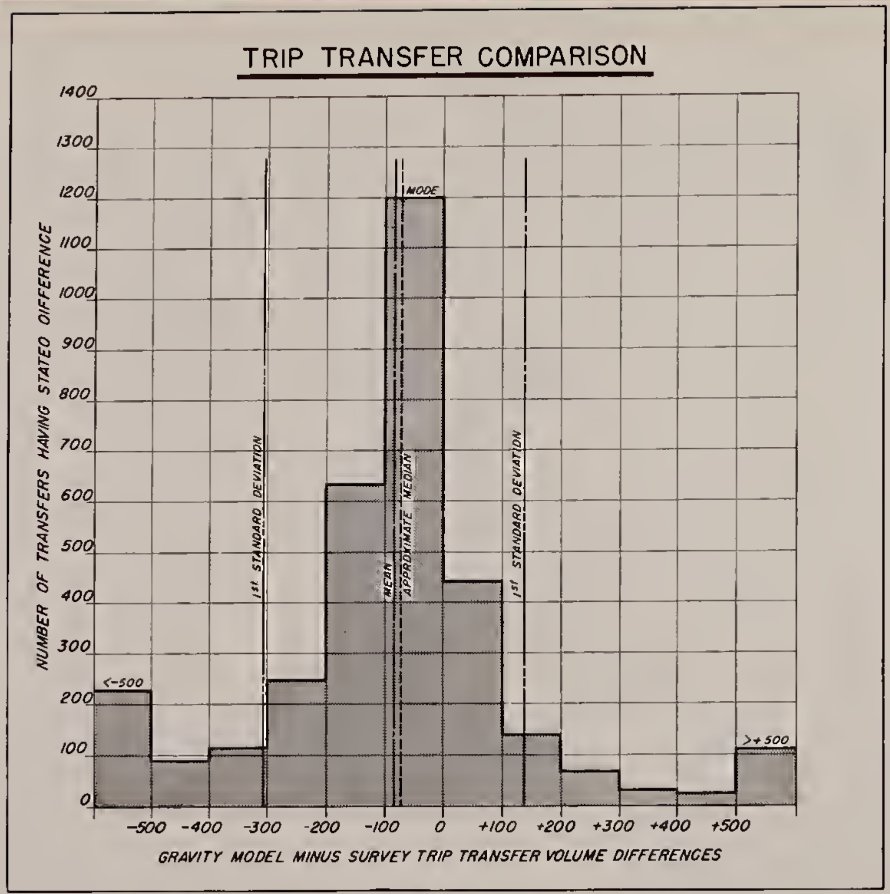


Exhibit T-14

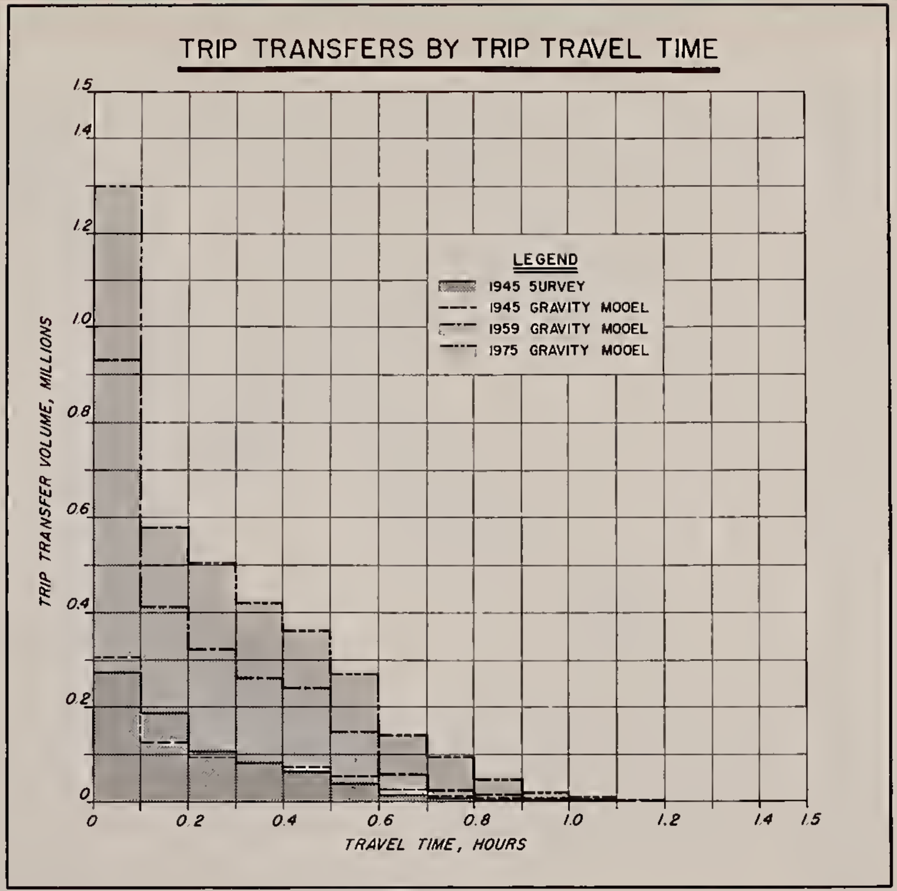


Exhibit T-16

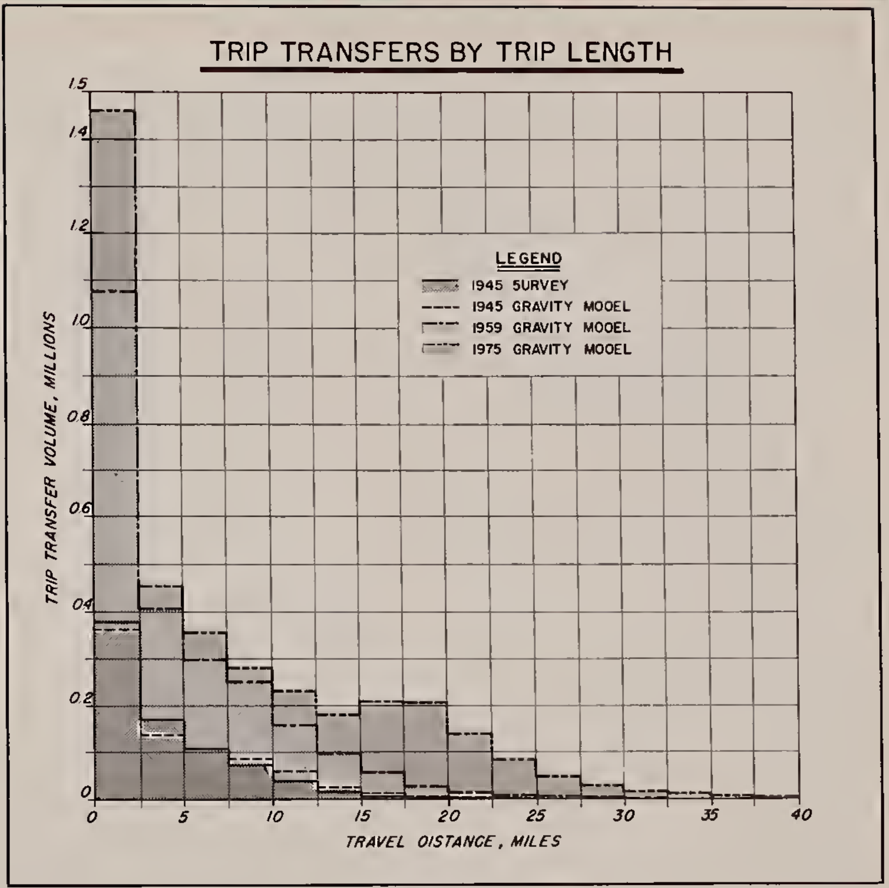


Exhibit T-18

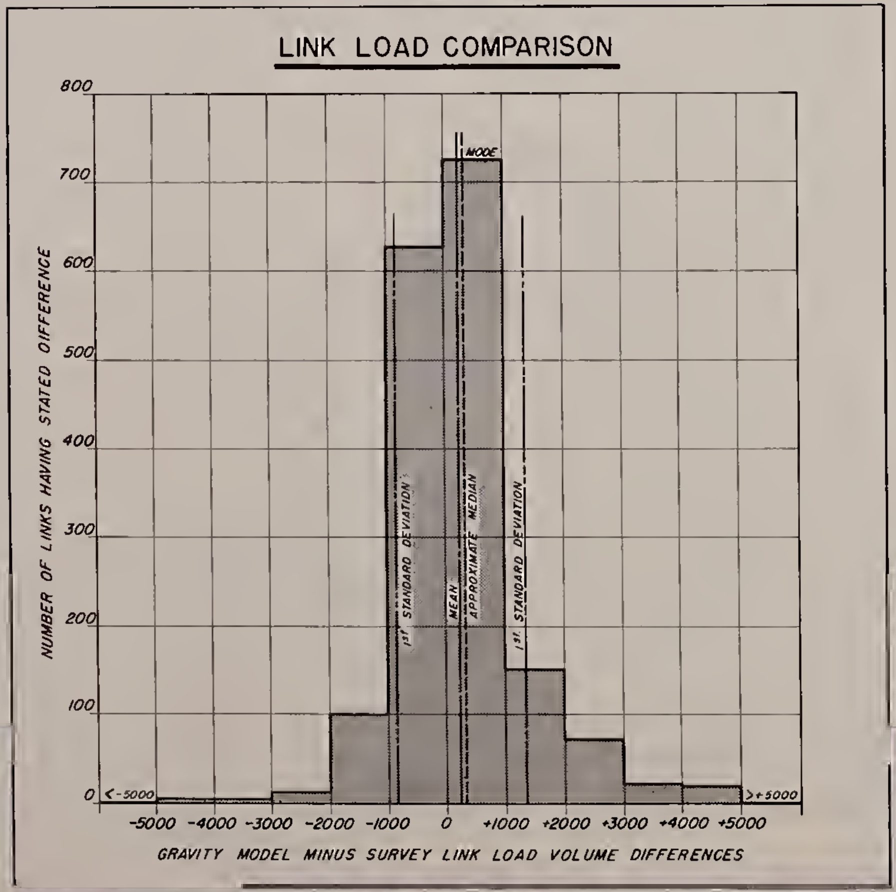


Exhibit T-15

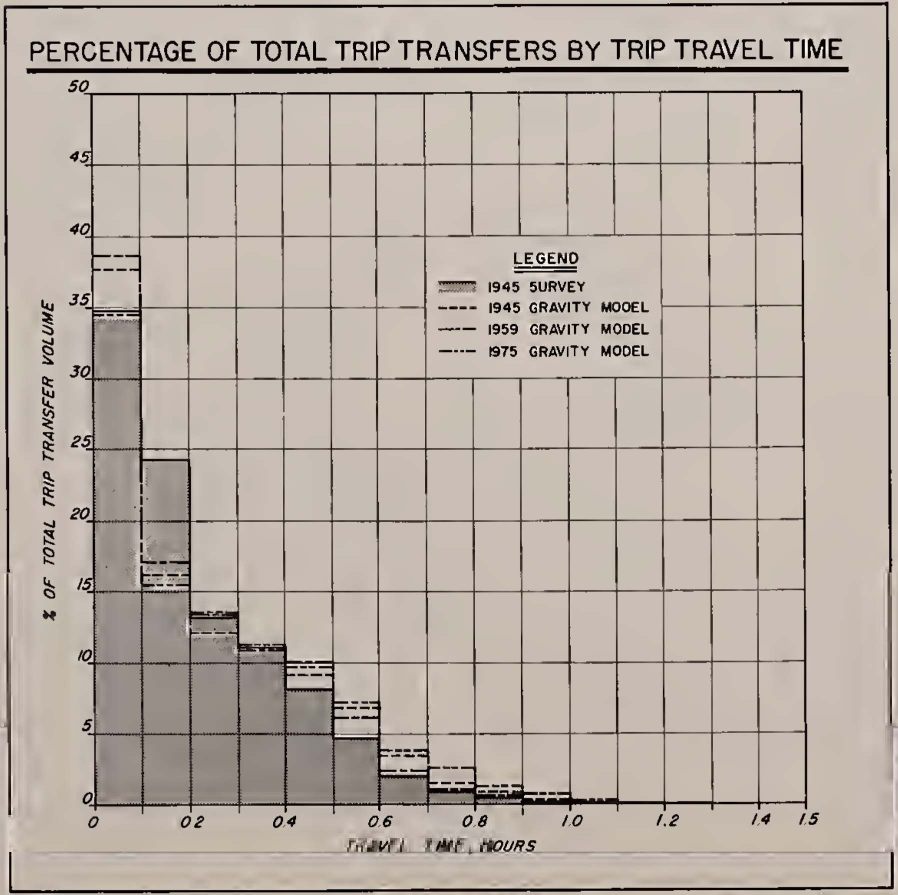


Exhibit T-17

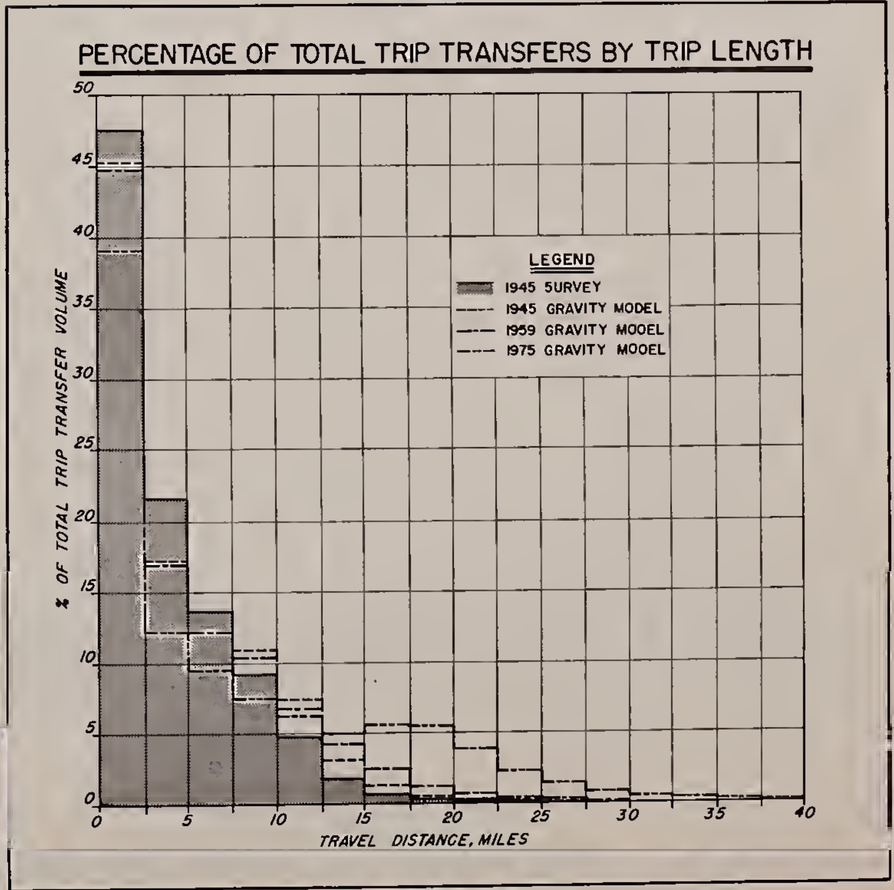
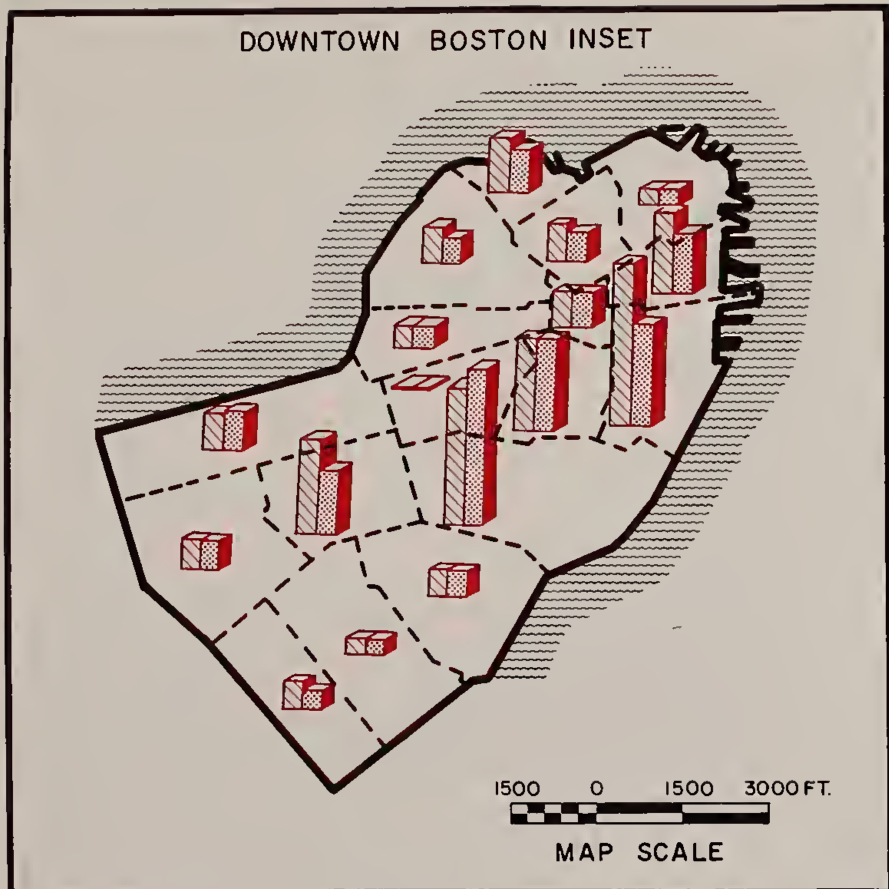


Exhibit T-19



STATISTICAL ANALYSIS OF COMPLETED MODEL

TRIP TRANSFER COMPARISON

Each trip transfer volume of the 1945 O. & D. survey was compared with the corresponding transfer of the computed gravity-model matrix. The frequency distribution of the differences between all sets of corresponding transfers was studied and the correlation coefficent for the final parameter set was computed to be 0.78; the mean of differences between transfer volumes stands at −83, and the standard deviation is 219 vehicles. This frequency distribution is illustrated in Exhibit T-14.

LINK-LOAD COMPARISON

The matrix of trip transfers of the 1945 O. & D. survey was assigned to the 1945 spider network and compared on a link-by-

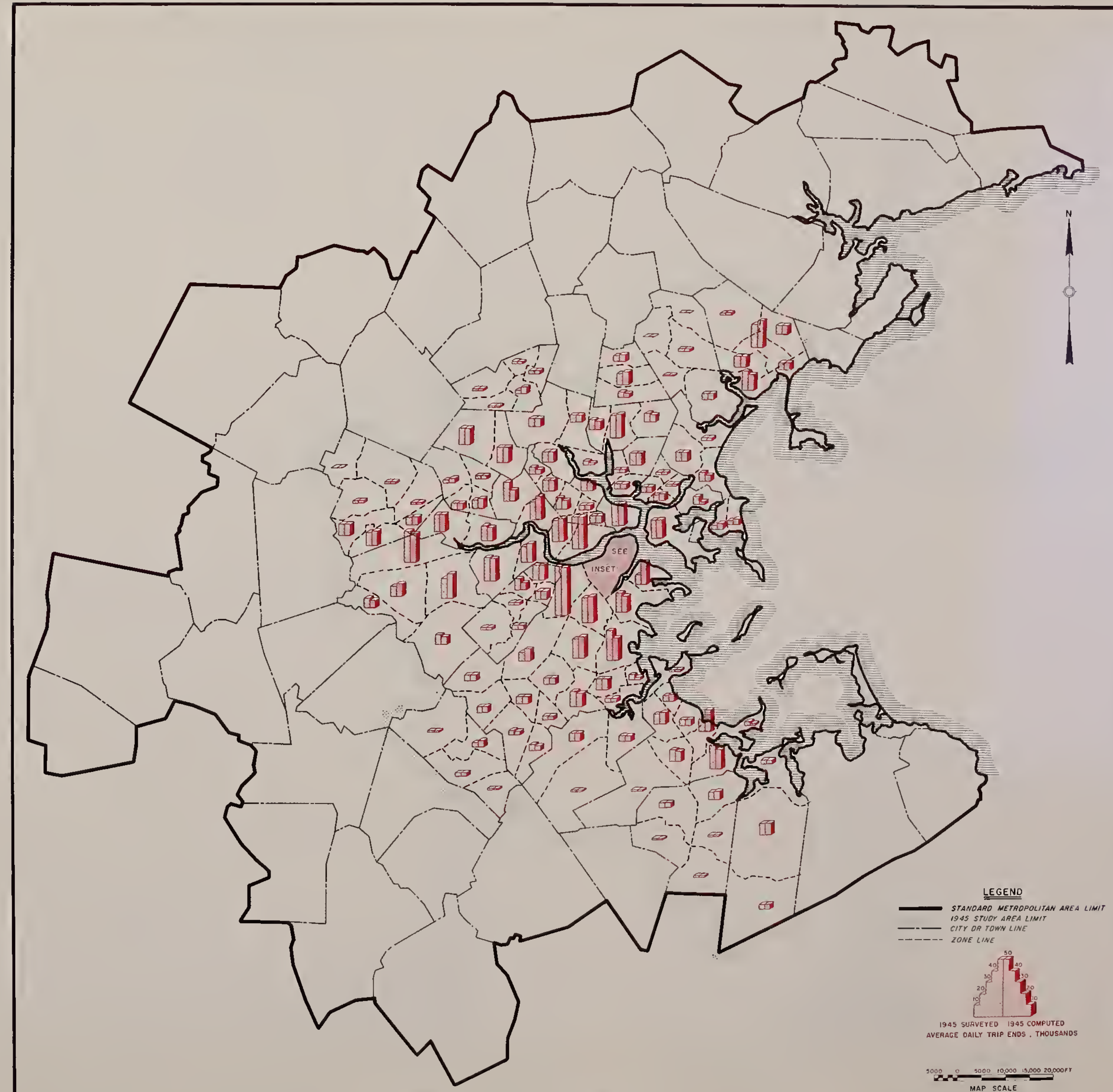
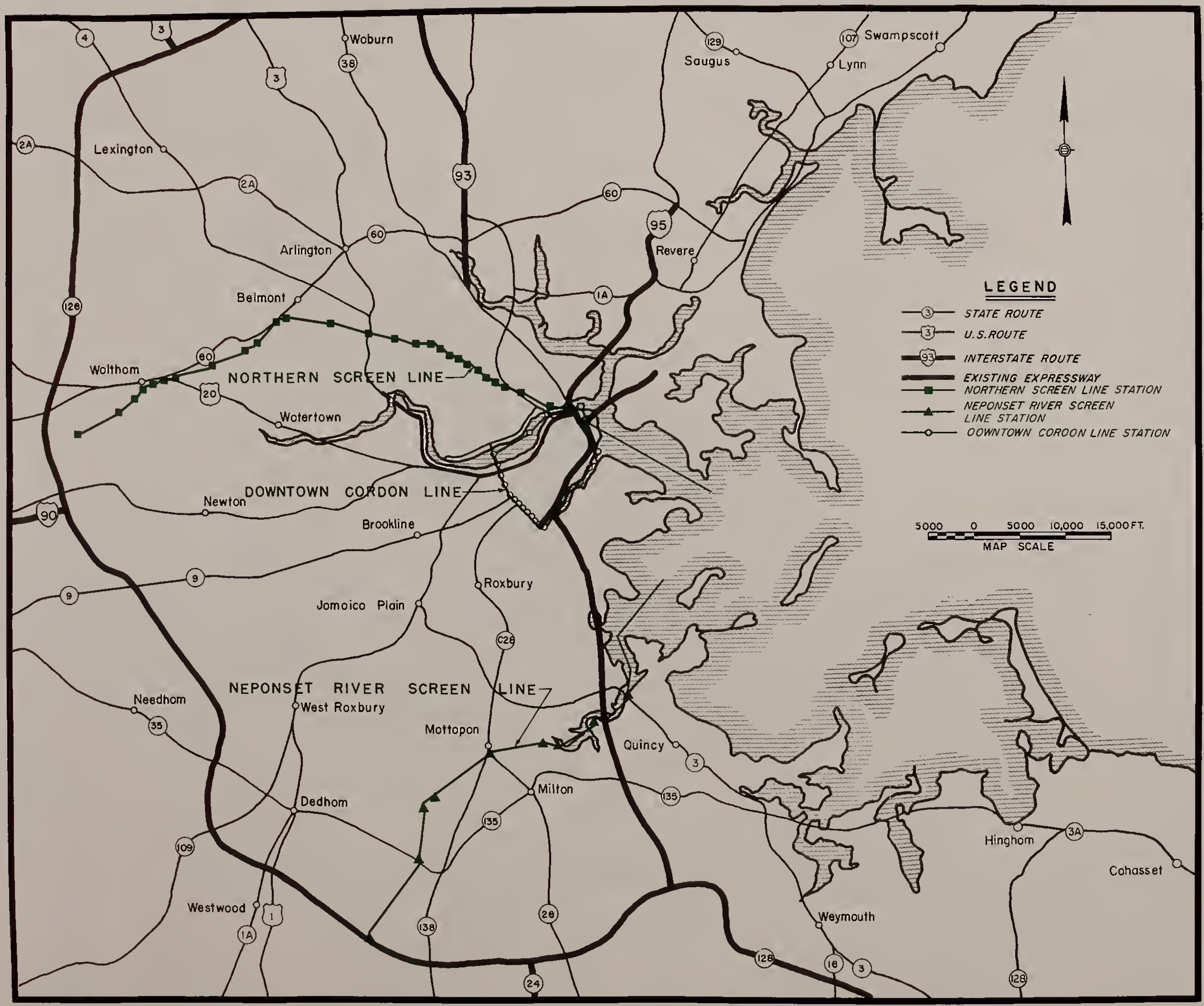


Exhibit T-20
1945 SURVEY vs. MODEL TRIP ENDS



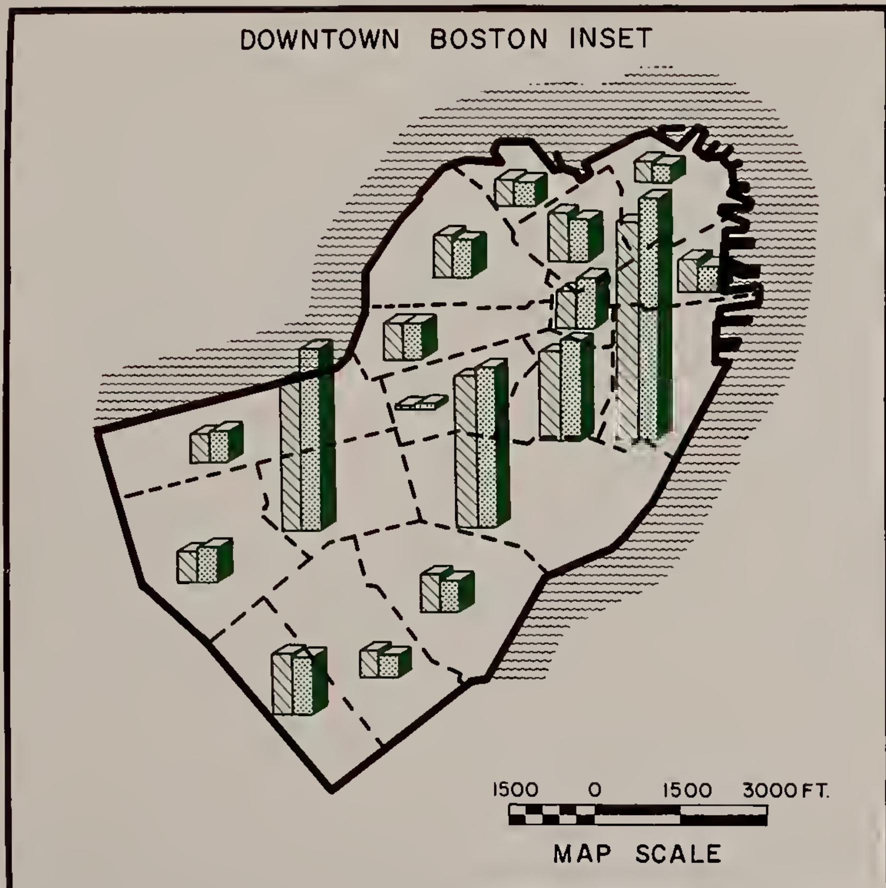
link basis with an identical assignment of the computed matrix. The frequency distribution of the differences between the volumes assigned to the link from the survey matrix and those from the computed matrix was determined and the correlation coefficient for the final set was computed to be 0.96; the mean difference stands at +249 vehicles, and the standard deviation is 1101 vehicles. This frequency distribution for the final parameter set is illustrated in Exhibit T-15.

TRAVEL TIME AND DISTANCE COMPARISONS

Trip transfers of the 1945 O. & D. survey were grouped according to their travel times, as assigned to the 1945 spider network, in six-minute increments. The same process was applied to the 1945 computed trip transfer matrix, and the resulting curves compared, both on a volume and percentage basis; these curves are shown in Exhibits T-16 and T-17, respectively. The correlation coefficient for the comparison of the "survey" curve with the "computed" curve is 0.98. Also shown in these figures are the curves for the 1959 computed traffic and the 1975 forecast traffic. It can be seen that while the trip transfer volumes in each travel-time range naturally increase with the years, the percentage volume in each range remains essentially constant over the years. Thus it may be generalized that whatever the status of the highway system, the time spent in travel for a given trip purpose will remain approximately the same.

A similar process was applied to both the surveyed and computed trip transfer matrices to determine the transfer volumes which travel given distances, in two-and-one-half-mile increments. These curves were also treated on both a volume and percentage basis; the results are shown in Exhibits T-18 and T-19, respectively. The correlation coefficent for the two 1945 curves is 0.99. In this chart are also included curves for 1959 computed traffic and 1975 forecast traffic. It is interesting to note that on a percentage basis the volumes decrease in the lower ranges of travel distance and increase in the upper ranges with increasing years, reflect-

Exhibit T-21
SCREEN-LINE LOCATION MAP



ing improved travel conditions so that for a given travel time, a greater distance may be traveled. Also of interest is the shape of the curve in 1975, indicating a disproportionate increase in the number of trips of 15 to 20 miles length as compared to 1959. This increase in this range may be ascribed to the growth and, by 1975, solid establishment of communities satellite to Boston, and the resulting travel desires between them.

TRIP-END COMPARISON

The trip transfer matrices, surveyed and computed, for 1945 were summed over rows and columns to determine the number of trip ends in each zone or sector, and compared as shown in Exhibit T-20. The correlation coefficient for comparison of surveyed and computed trip-ends per zone is 0.968 for the down-

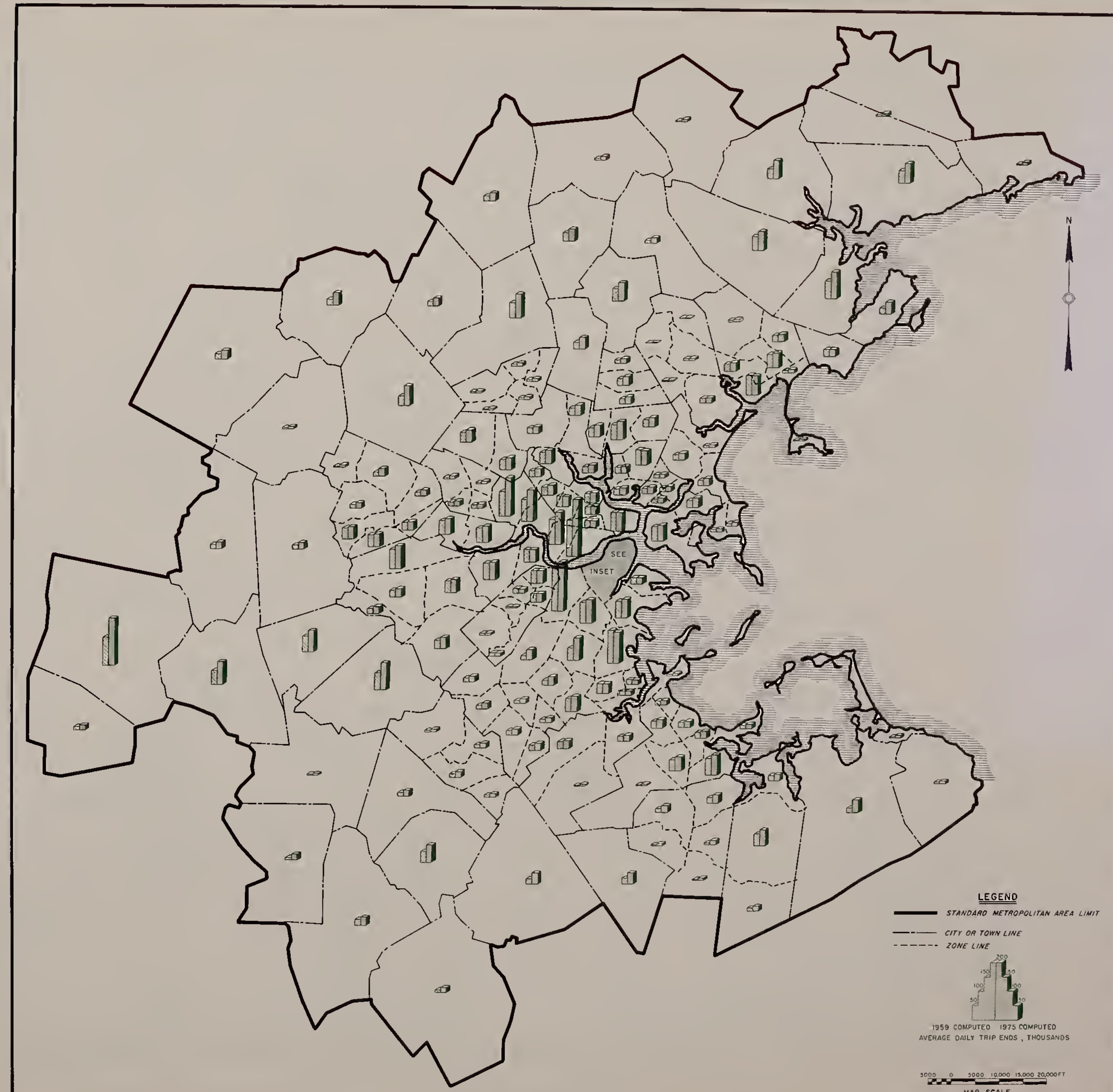


Exhibit T-22
BASE YEAR AND DESIGN YEAR TRIP ENDS

town zones and 0.975 for the entire 1945 Study Area. It can be seen that close agreement exists between the two sets of data, and further that there is no evidence of any systematic geographic error.

SCREEN-LINE ANALYSIS

For each major determination of parameter values a screen-line analysis was made. The results of these analyses for Parameter Sets 70, 90, 102, and 110 are shown in Table T-II. The screen-lines are illustrated in Exhibit T-21. It should be noted that the 1959 Neponset River screen-line was originally incomplete in that it did not include a station at Route 128; that is, it stopped short of defining completely that portion of the study area which it is intended to isolate. The increase in traffic on the Southeast Expressway between 1960 and 1961 was found from field traffic counts to be 35%, while other screen-line crossings were increasing from 3% to 6%, because a portion of Route 128 between Route 24 and Route 37 was completed in September 1960, thus inducing traffic which originates in the area of Dedham, Readville and points south to use the Southeast Expressway to get to Boston, a route to which the computer assignment program assigned traffic. When this Route 128 screen-line station is included, the resulting difference between surveyed and computed volumes crossing this screen-line is +3.8%, as shown.

TRAFFIC GENERATION AND DISTRIBUTION

With the best parameter sets determined for the gravity model by means of statistical and screen-line analyses, the trip transfer volumes for the year 1975 were computed, based on 1975 projected sociological data and the time paths of the 1975 spider network. The geographical distribution of the generated and attracted trip-ends for the design year 1975 are shown in Exhibit T-22, together with those for the base year, 1959. As an indication of the travel times upon which this distribution is

Exhibit T-23
SURVEY YEAR AND DESIGN YEAR ISOCHRONES

TABLE T-III

CONSOLIDATED 1975 PROJECTED TRIP TRANSFERS

Average Daily Traffic Between Districts

(In Hundreds of Vehicles, To Nearest Hundred)

District / Station Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	District / Station Group
NE	117	12	9	9	39	4	5	20	7	11	34	8	9	8	7	8	9	34	15	7	2	4	2	11	1	58	47	2	1	6	*	3	NE
N	268	22	20	26	97	11	12	44	15	22	53	26	22	20	16	14	17	65	49	21	5	8	4	20	2	34	61	58	3	13	1	5	N
NW	228	13	18	30	122	12	12	42	12	13	38	33	37	46	31	17	15	22	39	67	9	12	4	16	2	12	11	5	34	20	1	7	NW
W	263	13	16	23	122	22	22	68	17	12	26	15	39	53	65	29	24	21	18	21	22	24	7	26	3	10	8	2	5	203	1	13	W
SW	155	8	8	10	49	7	9	39	10	6	12	6	12	13	18	30	21	11	6	6	5	18	13	30	3	5	4	1	2	12	33	64	SW
S	362	17	18	21	100	15	19	84	34	13	25	13	22	23	34	66	62	22	11	10	10	35	108	130	8	10	8	2	3	16	2	32	S
SE	269	13	14	15	70	10	12	54	22	11	20	10	15	13	28	29	41	18	9	7	5	14	18	165	40	8	6	1	2	11	1	11	SE
District																																	**District**
1.	1505	192	80	341	556	115	185	405	130	272	346	277	262	131	173	388	282	278	194	96	70	139	196	541	48	108	56	50	16	80	23	68	1.
2.		180	13	23	51	7	9	24	11	97	54	21	17	10	11	19	16	68	17	7	4	8	9	30	3	17	11	3	1	6	1	4	2.
3.			68	35	40	7	9	12	5	28	33	27	20	9	11	17	12	24	16	8	4	7	9	26	3	8	4	4	1	5	1	3	3.
4.				290	380	30	29	69	16	35	98	124	78	27	33	31	24	38	40	22	10	13	11	35	3	13	8	7	4	13	2	6	4.
5.					945	124	136	177	31	83	245	87	253	95	122	120	77	92	95	62	40	55	52	136	14	36	19	21	10	43	9	22	5.
6.						159	69	49	8	10	18	16	47	22	48	27	18	12	11	8	10	13	9	25	2	5	3	3	1	11	2	4	6.
7.							111	117	12	11	20	17	35	20	46	49	27	15	12	8	12	18	12	31	3	6	4	3	1	12	2	7	7.
8.								209	30	35	53	44	67	37	65	184	94	42	33	19	22	44	49	120	10	18	9	8	3	22	6	18	8.
9.									115	14	19	15	15	9	12	30	35	16	11	6	5	10	17	54	4	7	4	3	1	6	1	5	9.
10.										193	144	38	22	12	13	19	17	117	22	10	4	8	8	27	3	21	15	3	2	7	1	4	10.
11.											709	160	64	30	26	32	27	157	91	28	10	14	14	47	5	35	25	13	4	14	2	8	11.
12.												251	83	31	21	21	19	41	74	31	8	10	8	28	3	14	10	9	4	11	1	5	12.
13.													408	131	78	37	26	31	40	39	19	23	13	39	4	13	8	6	7	23	3	9	13.
14.														449	108	28	16	19	26	42	34	31	11	28	3	9	6	5	7	29	3	10	14.
15.															481	66	26	19	19	23	62	71	16	40	4	9	5	4	4	38	5	15	15.
16.																501	156	27	31	13	18	105	74	91	7	12	7	4	3	19	5	29	16.
17.																	492	24	15	9	8	30	70	158	9	10	6	4	2	12	3	15	17.
18.																		667	53	17	7	12	12	35	5	101	52	8	3	12	2	7	18.
19.																			737	40	8	11	7	25	3	27	26	18	4	13	2	5	19.
20.																				444	11	12	5	15	2	10	7	7	8	14	2	5	20.
21.																					241	30	6	14	1	4	3	2	3	20	2	7	21.
22.																						430	25	46	4	6	4	2	3	21	6	40	22.
23.																							238	99	5	6	4	1	1	8	2	22	23.
24.																								1106	62	19	12	5	3	19	6	31	24.
25.																									199	2	2	1	*	3	1	3	25.
26.																										797	68	5	2	7	1	4	26.
27.																											445	4	1	4	1	2	27.
28.																												97	1	3	*	1	28.
29.																													83	3	*	1	29.
30.																														1013	3	8	30.
31.																															59	7	31.
32.																																297	32.

*Less than 50 vehicles

DISTRICT DEFINITION
(See Key Map)

NO.	LOCALITY	NO.	LOCALITY
1.	Downtown Boston	21.	Wellesley, Weston
2.	East Boston, Winthrop	22.	Dedham, Needham, Westwood
3.	Charlestown	23.	Canton, Milton, Randolph
4.	Somerville	24.	Braintree, Quincy, Weymouth
5.	Cambridge	25.	Cohasset, Hingham, Hull
6.	Brighton	26.	Beverly, Hamilton, Manchester, Marblehead, Salem, Wenham
7.	Brookline	27.	Danvers, Middleton, Peabody
8.	Roxbury	28.	North Reading, Wilmington
9.	South Boston	29.	Concord
10.	Chelsea, Revere	30.	Ashland, Framingham, Natick, Wayland
11.	Everett, Malden, Melrose	31.	Dover, Medfield
12.	Medford, Winchester	32.	Norwood, Sharon, Walpole
13.	Arlington, Belmont, Watertown		
14.	Waltham		
15.	Newton		
16.	Hyde Park, Jamaica Plain, West Roxbury		
17.	Dorchester		
18.	Lynn, Nahant, Saugus, Swampscott		
19.	Lynnfield, Reading, Stoneham, Wakefield, Woburn		
20.	Bedford, Burlington, Lexington, Lincoln		

KEY TABLE FOR NETWORK 3 INTERCHANGES

Code No.	Expressway	Interchange Location
012	Route 128	Bass Avenue, Gloucester
061	Interstate 95	Newburyport Turnpike, Danvers
98	Route 128	Massachusetts Turnpike, Weston
99	Mass. Turnpike	Washington Street, West Newton
100	Mass. Turnpike	Centre Street, Newton
101	Mass. Turnpike	Cambridge Street, Brighton
103	Mass. Turnpike	Central Artery, Boston
141	Route 3	Burlington Road, Bedford
461	Route 24	West Street, Stoughton
600	—	Broadway, Lynn
601	—	Highland Avenue, Lynn
602	—	Boston Street, Salem
603	—	North Street, Salem
604	—	Cabot Street, Beverly
605	—	Loring Avenue, Salem
610	Central Artery	Dover Street, Boston
611	Northeast	City Square, Charlestown
613	Central Artery	Causeway Street, Boston
614	Central Artery	Sumner Tunnel, Boston
615	Central Artery	State Street, Boston
616	Central Artery	Northern Avenue, Boston
617	Central Artery	Congress Street, Boston
618	Central Artery	Beach Street, Boston
621	Northeast	Everett Avenue, Chelsea
622	Northeast	Arlington Street, Chelsea
623	Northeast	Carter Street, Chelsea
624	Northeast	Webster Avenue, Chelsea
625	Northeast	Revere Beach Parkway, Revere
626	Northeast	Sargent Street, Revere
627	Northeast	Squire Road, Revere
628	Interstate 95	Andover Street, Danvers
629	Interstate 95	Center Street, Danvers
631	Southeast	Southampton Street, Dorchester
632	Southeast	Columbia Road, Dorchester
633	Southeast	Freeport Street, Dorchester
634	Southeast	Gallivan Boulevard, Neponset
636	Southeast	Granite Avenue, Milton
637	Southeast	West Squantum Street, Milton
638	Southeast	Willard Street, Quincy
639	Southeast	Furnace Brook Parkway, Quincy
644	Southwest	Centre Street, Roxbury
645	Southwest	Morton Street, Jamaica Plain
646	Southwest	Cummins Highway, Hyde Park
647	Southwest	West Street, Hyde Park
648	Southwest	Milton Street, Readville
649	Southwest	Route 128, Canton
654	Mass. Turnpike	Inner Belt, Boston
655	Mass. Turnpike	Massachusetts Avenue, Back Bay
656	Mass. Turnpike	Huntington Avenue, Back Bay
657	Mass. Turnpike	Arlington Street, Boston
658	Inner Belt	Erie Street, Cambridge
659	Mass. Turnpike	Cochituate Road, Framingham
660	Mass. Turnpike	Worcester Turnpike, Framingham
661	Route 2	Spring Street, Lexington
662	Route 2	Waltham Street, Lexington
663	Route 2	Pleasant Street, Lexington
664	Route 3	Route 2, Arlington
665	Route 3	Park Avenue, Arlington
666	Route 3	Pleasant Street, Arlington
667	Route 3	Alewife Brook Parkway, Cambridge
671	Route 3	Main Street, Medford
672	Route 3	Mystic Valley Parkway, Medford
673	Route 3	Massachusetts Avenue, Cambridge
674	Route 3	Massachusetts Avenue, Lexington
675	Route 3	Woburn Street, Lexington
681	Interstate 93	Route 128, Reading
682	Interstate 93	Montvale Avenue, Woburn
683	Interstate 93	Park Street, Stoneham
684	Interstate 93	Main Street, Stoneham
685	Interstate 93	Fellsway West, Medford
686	Interstate 93	Salem Street, Medford
687	Interstate 93	Mystic Valley Parkway, Medford
688	Interstate 93	McGrath Highway, Somerville
691	Inner Belt	Southwest Expressway, Roxbury
692	Inner Belt	Brookline Avenue, Boston
693	Inner Belt	Beacon Street, Boston
695	Inner Belt	Harvard Street, Cambridge
696	Inner Belt	Northwest Expressway, Somerville
697	Inner Belt	Interstate Route 93, Somerville
698	Inner Belt	Prison Point Bridge, Charlestown
701	Route 128	Route 1, Lynnfield
702	Route 128	Walnut Street, Lynnfield
703	Route 128	Charles Avenue, Wakefield
704	Route 128	Vernon Street, Wakefield
705	Route 128	Salem Street, Wakefield
706	Route 128	North Avenue, Wakefield
707	Route 128	Main Street, Reading
708	Route 128	Washington Street, Woburn
709	Route 128	Main Street, Woburn
710	Route 128	Winn Street, Burlington
711	Route 128	Cambridge Street, Burlington
712	Route 128	Middlesex Street, Burlington
713	Route 128	Route 3, Burlington
714	Route 128	Bedford Street, Lexington
715	Route 128	Marrett Road, Lexington
716	Route 128	Route 2, Lexington
717	Route 128	Tropelo Road, Waltham
718	Route 128	Winter Street, Waltham
719	Route 128	South Avenue, Weston
721	Route 128	Washington Street, Newton
722	Route 128	Worcester Turnpike, Wellesley
723	Route 128	Highland Avenue, Needham
724	Route 128	Great Plain Avenue, Needham
725	Route 128	West Street, Dedham
726	Route 128	High Street, Dedham
727	Route 128	Route 1, Dedham
728	Route 128	East Street, Westwood
729	Route 128	Railroad Station 128, Dedham
730	Route 128	Washington Street, Canton
731	Route 128	Ponkapoag Trail, Milton
732	Route 128	Fall River Expressway, Randolph
733	Route 128	North Main Street, Randolph
734	Route 128	Granite Street, Braintree
740	Route 128	Andover Street, Peabody
741	Route 128	Lowell Street, Peabody
742	Route 128	Weston Street, Waltham
743	Route 128	Endicott Street, Danvers
744	Route 128	High Street, Danvers
745	Route 128	Eliot Street, Danvers
746	Route 128	Dodge Street, Beverly
747	Route 128	Brimbal Avenue, Beverly
748	Route 128	Essex Street, Beverly
749	Route 128	Hart Street, Wenham
750	Route 128	Pine Street, Manchester
751	Route 128	School Street, Manchester
819	Inner Belt	Southeast Expressway, Boston
820	East Boston	Airport Road, East Boston
821	East Boston	McClellan Highway, East Boston
822	—	Beach Street, Revere
823	Interstate 95	Salem Turnpike, Saugus
824	Interstate 95	Ballard Street, Saugus
825	Interstate 95	Walnut Street, Lynn
826	Interstate 95	Waycross Road, Lynn
827	Interstate 95	Lynnfield Street, Lynn
828	Interstate 95	Route 128, Peabody
829	Interstate 95	Lowell Street, Peabody
831	Southeast	Route 128, Braintree
832	Southeast	Washington Street, Braintree
833	Southeast	Union Street, Braintree
834	Southeast	Main Street, Weymouth
835	Southeast	Derby Street, Hingham
841	Interstate 95	Coney Street, Walpole
842	Interstate 95	Neponset Street, Norwood
843	Northwest	Concord Avenue, Cambridge
862	Northwest	Massachusetts Avenue, Cambridge
863	Northwest	Beacon Street, Somerville
866	Route 2	Bedford Road, Lincoln
867	Route 2	Cambridge Turnpike, Concord
868	Route 2	Elm Street, Concord
881	Interstate 93	Lowell Street, Wilmington
882	Interstate 93	Concord Street, Wilmington
883	Interstate 93	Middlesex Street, Wilmington
894	Inner Belt	Northeast Expressway, Boston

Exhibit T-24

DISTRICT AND INTERCHANGE KEY MAP

TABLE T-IV
STATISTICAL DATA

Item	1945 Survey	1945 Model	Model-Survey Difference	1959 Model	1975 Model	1959-1975 Increase
	Year & Mode					
Total Trips	796,101	800,085	+0.5%	2,409,842	3,745,988	55%
Vehicle-Haurs	172,306	193,936	+13%	538,655	974,724	81%
Vehicle-Miles	3,250,055	3,776,070	+16%	12,350,541	29,614,661	140%
Moximum Travel Time, hours	1.4	1.4	0	1.2	1.6	33%
Average Trovel Time, hours	0.22	0.24	+ 9%	0.22	0.26	18%
Maximum Travel Distance, miles	30.0	32.5	+ 8%	40	50	25%
Average Travel Distance, miles	4.08	4.72	+16%	5.13	7.91	54%
Average Speed, mph	18.9	19.5	+ 3%	22.9	30.4	33%

based, Exhibit T-23 shows the time-distance contours (isochronic lines) of the 1975 spider network, including expressways. As a basis for comparison of travel times without expressways, the 1945 isochronic lines are also included therein.

A consolidated trip transfer matrix for 1975 is presented in Table T-III, while a key map for this matrix is illustrated in Exhibit T-24. Table T-IV summarizes the major statistical data of the foregoing statistical analysis, together with comparable data for the base year 1959 and the design year 1975.

TRAFFIC ASSIGNMENT

INTRODUCTION

The National Policy of the American Association of State Highway Officials is generally recognized as the primary guide to the methods and procedures for the purpose of determining traffic assignments to be used as the basis for design of expressway-type facilities. There follows below a comparison of the procedure described therein with those which were required by virtue of the use of the mathematical model.

As indicated in the National Policy,[51] the first step was the "establishment of all motor-vehicle trips and their desire lines in the area for a representative day during the current year." This data was arrived at by considering trips and desire lines for the year 1945, and determining methods of expansion which, when applied to this data, would provide acceptable values for screen-line crossings as compared with actual field-survey values in the base year; the expansion was effected by means of the gravity model previously described.

At the same time that the first step was being carried out, work was also being carried forward on the second step, the "preliminary location and design studies for the arterial highway," hereinafter referred to as initial basic design. The third step, the "determination of traffic growth factors" is, of course, an integral part of the development of the gravity model, and as such is expected to be subject to a much smaller range of error than would be the case under other methods in current usage. This smaller range is due to the fact that almost all of the forecasting is applied to the sociological data cited above, the growth of which is much more accurately predictable. The "expansion of current zone-to-zone travel to the future year" is a direct result of the completion of the gravity model for the base year and its application to the projected sociological data of the future year.

The fourth step, the "assignment of the expanded daily trips to the arterial highway improvement" was also undertaken as stipulated in the National Policy, by initially "superimposing on an area map which shows all existing facilities, the location and preliminary design of the arterial in question, as well as the other highway improvements contemplated during the period of time designated for design." The use of the gravity model required, of course, that this step be taken as early as possible, and as noted above it was actually accomplished concurrently with the first step.

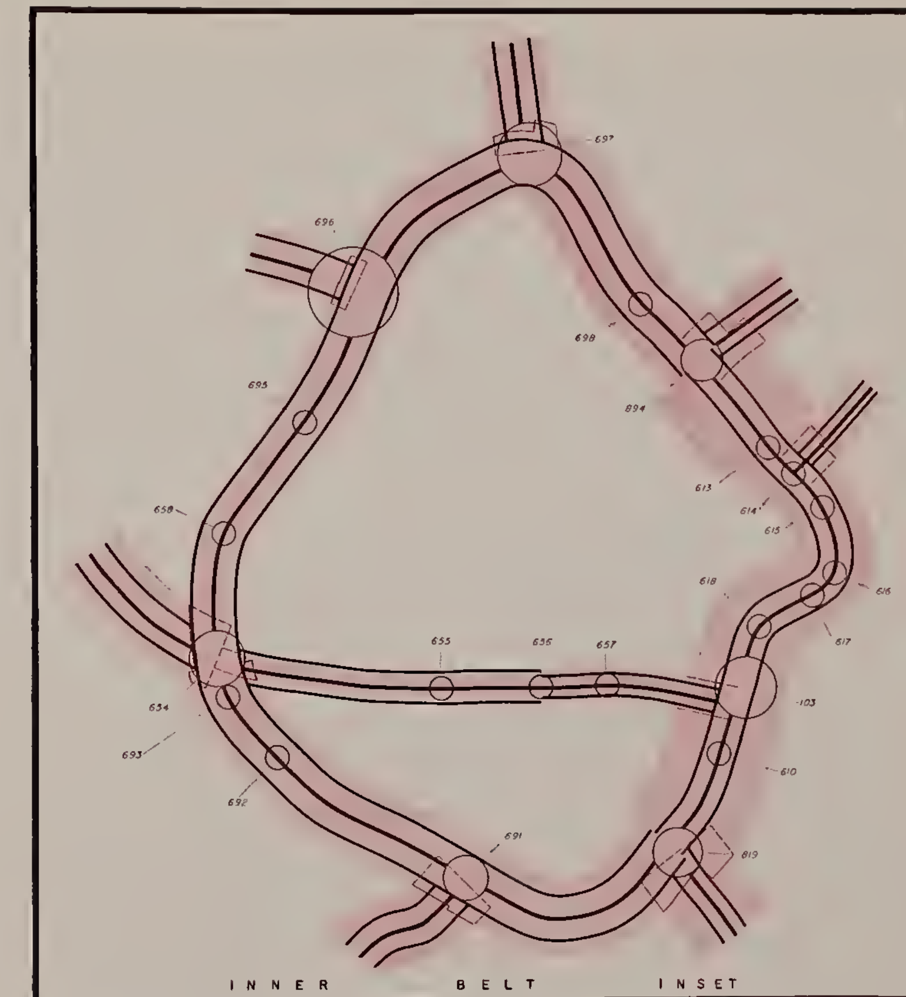
Immediately thereafter the second item in the assignment step, i.e., the estimation of "the overall speeds of traffic on the contemplated improvements . . . on the basis of experience on comparable facilities," and the determination of "actual overall speeds and travel times on existing facilities . . . by field surveys," was undertaken and completed. At this point all data had been accumulated which were necessary for the traffic assignment.

FREE ASSIGNMENT

The basic assignment of traffic for the subject Study was undertaken by making use of the all-or-none method, illustrated as a diversion curve in Exhibit T-2, to indicate its relationship to those used by others. This process assigns all traffic between any single pair of origin and destination points to the least-travel-time route.

In view of the information collected on diversion procedures, it is evident that free assignment traffic volumes, or volumes determined by assignment on an all-or-none basis, as illustrated in Exhibit T-25, represent the future potential demand for expressway service and are not to be construed as expected expressway traffic.

The free assignment figures arrived at for the year 1975 are, however, reliable predictions of the manner in which traffic



will desire to move if the necessary facilities are available, based upon the potential growth of the entire metropolitan community. To the extent that such facilities are not made available, such growth will be retarded, and the central cities will be gradually depleted in favor of the suburbs.

The question naturally arises as to whether the existing arterial streets will be able to carry those volumes which are beyond the proposed capacities of the expressways. The answer can be determined quite readily by dividing the study area into segments as follows: from the Central Business District radial lines are drawn roughly midway between radial expressways, in such a way as to define the boundaries of the area of influence of each radial

Exhibit T-25
1975 FREE ASSIGNMENT VOLUMES

expressway; each of these pie-shaped sectors is then a "corridor" served by the radial expressway which bisects it. Then around the Central Business District, and at varying distances from its center, roughly circular boundaries are described, which divide the area into cordon rings, as shown in Exhibit T-26. The desire for radial traffic movement, as shown by the free assignment at each cordon in each corridor may then be compared with the total of the arterial and expressway capacity at this cordon line; the difference between the two is the surplus or deficiency in the total capacity of the corridor to carry the projected radial traffic.

The capacity per hour of each major street was estimated on the basis of existing physical and traffic conditions, and compared for verification wherever possible with available traffic counts. The capacity per hour of each expressway was determined as explained hereinafter.

The Cordon-Corridor Analysis results, shown in Table T-V, indicate the amount of capacity deficiency at each cordon line in each corridor of influence of the radial expressways, on the above-noted basis. It is apparent that the capacities of facilities presently proposed or provided are grossly deficient in their ability to provide for the indicated traffic volumes. It should be evident that the proposed system of expressways, without the provision of auxiliary facilities or the improvement and extension of existing transportation facilities, will be inadequate in serving to foster the healthy growth of the Boston Metropolitan Area assumed at the outset of this Study. At the same time, elementary consideration of the traffic volumes presented yields the conclusion that an attempt to provide for these movements solely by the construction of additional expressways would result in a prohibitively expensive and impractical system.

TISRO ASSIGNMENT PROCEDURE

The free assignment of traffic to the Expressway System resulted in traffic volumes far in excess of available capacity on practically the entire system. While the free assignments were

Exhibit T-26
CORDON-CORRIDOR LOCATION MAP

based on a proven principle, i.e., all-or-none, for obtaining assignments which indicate desires, it was obvious that a far more sophisticated method of assignment would be necessary to obtain traffic volumes for design purposes.

With a desire for use which is much greater than the capacity of the Expressway System, and with the number of expressways predetermined and the location of each component expressway confined to a rather narrow corridor by terminal location controls, it followed that the exact location of each expressway would be relatively independent of the assignment. Therefore, the primary function of the assignments was to provide information upon which the design of the local interchanges could be predicated.

The method to be used to obtain assignments had to reflect the following requirements:

a. The volume assigned to any expressway link must not exceed the design capacity of an eight-lane expressway.

b. The assignments must reflect average driver behavior to the extent that such behavior is rational and may be stated in mathematical terms compatible with the model system.

c. The method used must be comprehensive enough to provide sufficient information upon which the design of local interchanges may be predicated.

Investigation revealed that somewhat similar problems had been programmed for electronic computer application elsewhere, but that either the basic conditions were completely dissimilar, or that sufficient progress of development had not been achieved to warrant adoption without some reservation. Major research effort, currently in progress by several organizations, is directed to the accurate simulation by electronic computer of actual traffic flow. However, the simulation of the actual distribution of traffic flow on all streets and highways within a metropolitan area would require computer storage of a number of alternative paths between each origin and destination together with their travel times and distances. These paths could then be incrementally loaded with the desire traffic, and the travel times and distances on each link in the network would then have to be recomputed as a function of link loading. These sets of data would have to be reconciled on a cyclical iterative basis, since the trip desires would be influenced by changes in travel times, and the link loadings would in turn be directly affected by resulting trip desires. The trip desires then would indicate either drastic reductions in desired average length of trips or the complete elimination of many desires. Although of extreme value in the operational phases of traffic engineering, this type of approach, if used, would have ultimately yielded:

a. the future restricted trip desires and required local interchange service, on the basis that no additional expressways or arterials are to be provided, i.e., using the preconceived fixed network,

b. the future traffic volumes as limited by the fixed capacities of this network, and

c. the speeds at which these volumes would travel.

In essence this information would indicate the limited additional growth of the Boston Metropolitan Area necessary to attain the capacity of this fixed network, and would ignore any of the growth to be derived from the socio-economic potential which has been forecast. Furthermore, under such an approach the travel desires based on the forecast of the 1975 socio-economic data would be curtailed rather than assigned to alternate paths, and the assignment to the alternate paths, therefore, would not be available for examination and use in planning of additional facilities.

In order to overcome the difficulties and weaknesses of such a flow-simulation method, two possible procedures, which may be described as follows, were seriously considered:

a. Systematic reduction of the assumed speeds on each link of the Expressway System so as to increase travel time on all those links for which the free assignment is in excess of capacity. The systematic adjustment of speed would be iterative and would continue until the volume assigned to each link of the system was equal to or less than the capacity of the link. With an increase in travel time on the expressway links, travel over the existing street net would require less time for a larger number of the shorter length trips and hence the volumes assigned to the Expressway System would be less than those obtained by free assignment.

b. Selection of reasonable values for speed on the various expressway links and the local street network and assignment of trips to the Expressway System in rank order of greatest time saved per trip via the Expressway System as compared to the local street network.

Both methods would yield valid expressway design assignments since they would eliminate from the Expressway System those trips with the least time saving, and the ramp assignments obtained would realistically reflect the use of the Expressway System by trips of sufficient length to justify its construction.

However, in regard to the first method, it was judged that such an iterative procedure may not be convergent, due to the

TABLE T-V
CORDON-CORRIDOR ANALYSIS

Corridor	Desire − Capacity = Deficiency	Cordon: Inner	Intermediate	Outer
Northeast	Desire	352,200	281,000	242,000
	Capacity	191,000	235,500	115,000
	Deficiency	161,200	45,500	127,000
Northern	Desire	258,300	215,100	165,000
	Capacity	184,200	186,000	147,100
	Deficiency	74,100	29,100	17,900
Northwest	Desire	257,500	213,700	193,900
	Capacity	193,200	197,500	183,800
	Deficiency	64,300	16,200	10,100
Western	Desire	291,200	279,400	225,400
	Capacity	214,200	270,000	193,300
	Deficiency	77,000	9,400	32,100
Southwest	Desire	303,400	322,100	206,500
	Capacity	236,400	227,000	160,800
	Deficiency	67,000	95,100	45,700
Southeast	Desire	341,000	322,400	298,100
	Capacity	177,000	155,000	166,800
	Deficiency	164,000	167,400	131,300

great number of links on which the speed would require adjustment, and due to the necessarily arbitrary speed reduction to be applied in proportion to the traffic volume on each link. Hence, the amount of time required to achieve a solution of the problem on an electronic computer could well have been excessive. In effect, this greater length of "machine time" would be spent to determine a value for that speed on each link of the Expressway System which, if increased, would result in congestion on the link because the assigned volume would then exceed the capacity. A different value for speed would be obtained for each link of the Expressway System; these values would have little use in the design process, and hence would be of academic interest only.

The second method considered would achieve the desired result without recourse to an iterative procedure, and hence would result in much less "machine time." Since it was not possible to make a reasonable estimate of the number of iterative steps which would be required to obtain a solution by the first method, and furthermore, since the second method would be equally capable of providing information for the design of local interchanges and frontage roads, and for the recommendation of supplemental facilities, the obvious choice became the second method outlined above.

The TIme-Saving-Rank-Order method, referred to as the "TISRO" method, was therefore developed and utilized as the basis for expressway design assignments. A detailed description of the theory of the TISRO assignment procedure is contained in Section 2 of Traffic Analysis and a description of the input and output of the computer program is contained in Section 3 under "TISRO Assignment Program."

Aside from the development of computer programs to obtain the TISRO assignments, a basic step involved the establishment of capacity volumes for each link of the Expressway System in order to set a limit for the volume to be assigned to each link. The capacity of each expressway included in this Study was based upon eight lanes of width, four lanes in each direction. The number of lanes on proposed expressways not included in this Study was supplied by the Department of Public Works, and the capacity of the existing Central Artery, the Southeast Expressway and the Northeast Expressway was based on six lanes. Direct connectors of major expressway interchanges and local interchange ramps were not restricted in capacity in order to obtain assignments which could be used as a basis for the design of these elements of the Expressway System.

For design purposes, the basic lane capacity was assumed to be 1500 vehicles per hour, a value applicable to urban express-

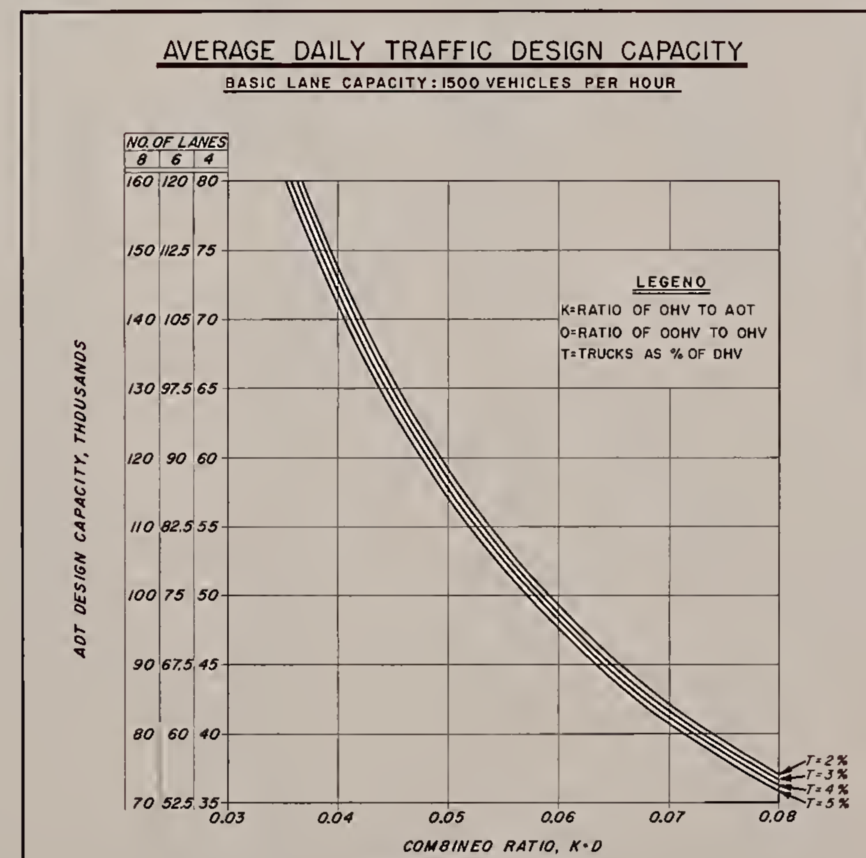


Exhibit T-27

ways with full control of access. Two-way average daily traffic (ADT) capacity was found on the basis of the AASHO formula:

$$C = \frac{100\,P}{100 + T\,(j-1)} \times \frac{5000\,N}{KD}$$

where
- C = two-way ADT capacity,
- P = lane capacity of 1500 vehicles per hour,
- T = percentage of trucks,
- j = equivalent number of passenger vehicles for each truck, taken as 2 for level terrain,
- K = design hour volume as a percentage of ADT,
- D = directional distribution during design hour as a percentage,

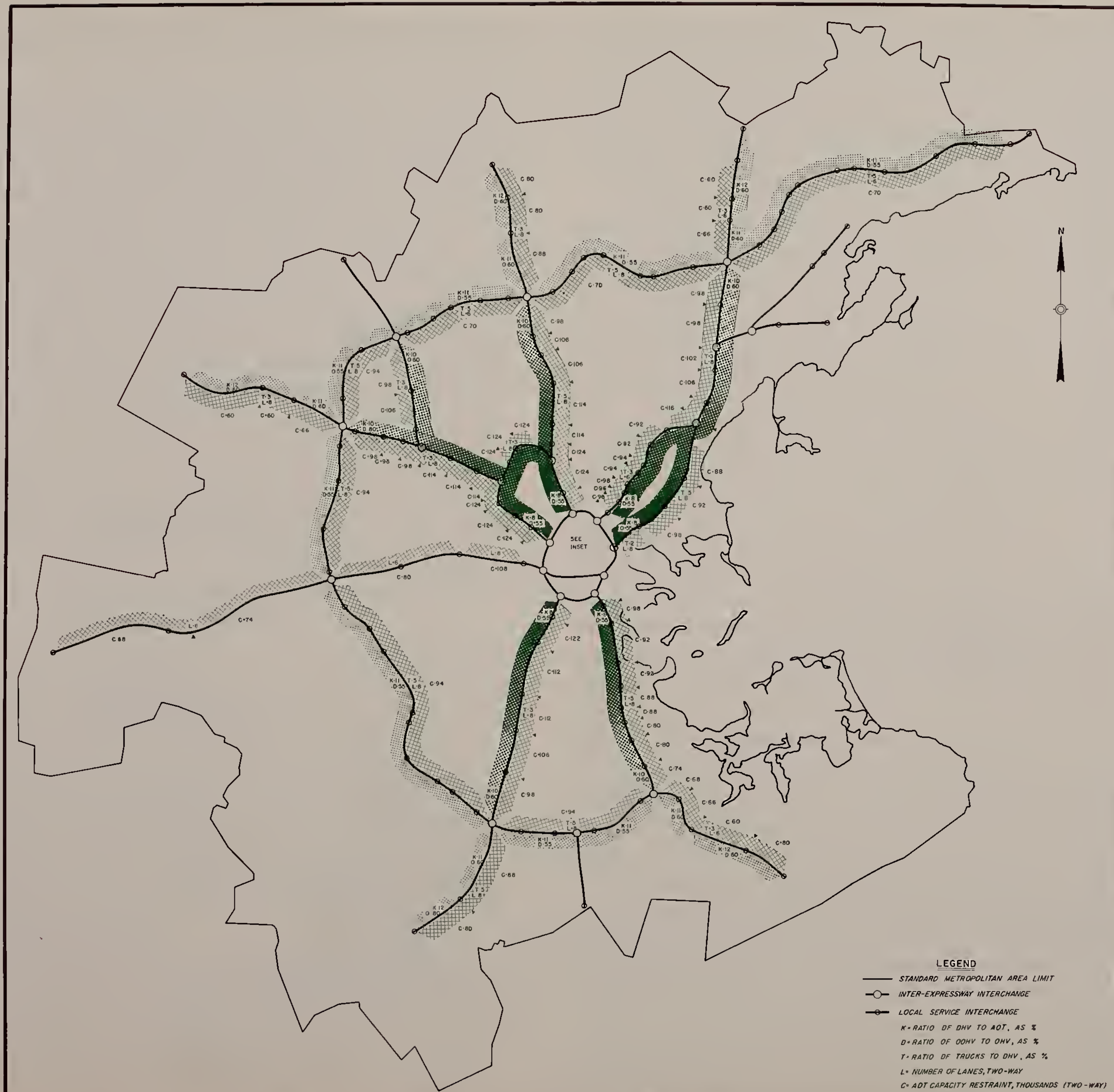
and
- N = total number of lanes.

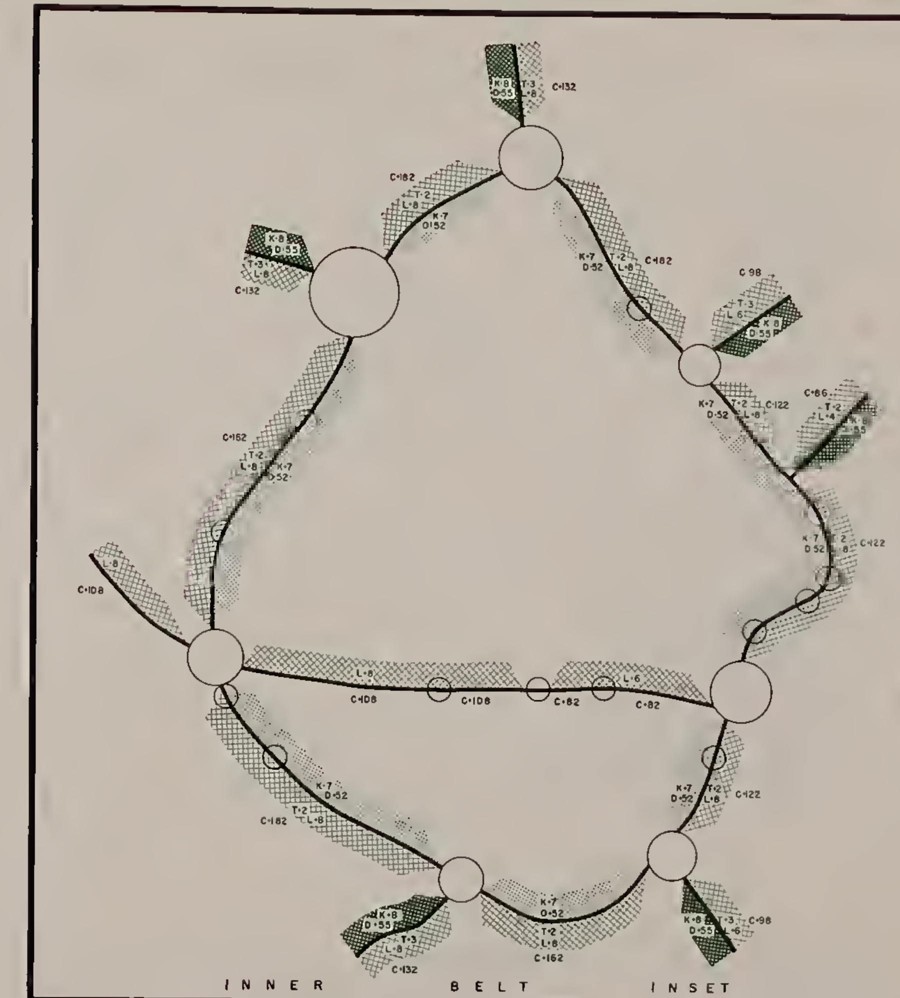
The values noted above were introduced into the formula and the curves of Exhibit T-27 were constructed for convenience. On the basis of observation of the operation of existing expressway facilities, projected rational values were chosen for K, D, and T, and on this basis ADT capacities for each section of the Expressway System were then determined. Values for the ADT capacity of each section of the Massachusetts Turnpike were derived directly from data published by the Turnpike Authority; these Turnpike capacity figures are considerably lower than those used for free expressways of the same number of lanes.

TISRO assignments were obtained for three separate networks of the Expressway System. The three networks which were used are described earlier in this Section of the Study, and are shown in Exhibit T-6. Typical controlling values and the resulting expressway capacity restraints used in the TISRO assignment procedure for Net 3 are indicated in Exhibit T-28. Specifically, design capacities used for the Expressway System are as follows:

a. The Central Artery: 122,000 vehicles per day.
b. The Northeast and Southeast Expressways at the Central Artery: 98,000 vehicles per day.
c. The Inner Belt: 162,000 vehicles per day.
d. Each radial expressway included in this Study, at its junction with the Inner Belt: 132,000 vehicles per day.

The trip transfer matrix previously described as the output of the gravity model was used as input for the TISRO assignment program. The TISRO method first lists trip transfers in order of time-saving, from greatest to smallest. The transfers are then assigned to the expressways up to the capacity limit of the expressway, or the free assignment value, whichever is less. As each transfer in the electronic computer process is about to be loaded on a link, the total loading which would result is compared with the stipulated capacity. If the resultant loading were to be greater than capacity, that transfer is not loaded, and furthermore, it is removed from all previous expressway links to which it was assigned. It is instead assigned to the quickest alternate street path.





Other transfers with lesser time-savings may then be loaded on that expressway link if they do not cause the volume on that expressway link, or any other link, to exceed capacity. When an expressway link has thus been loaded to capacity, any other transfer which would use that link and has lesser time-saving than those already loaded is then also assigned to the street system.

ANALYSIS OF TISRO ASSIGNMENT RESULTS

Exhibit T-29 shows the volumes of 1975 traffic as related to time-savings, which are assigned to the 1975 Network 3 under free assignment, and which remain on expressways under TISRO assignment. The difference between the two is assigned to the

Exhibit T-28

TRAFFIC FACTORS AND APPLIED CAPACITY RESTRICTIONS

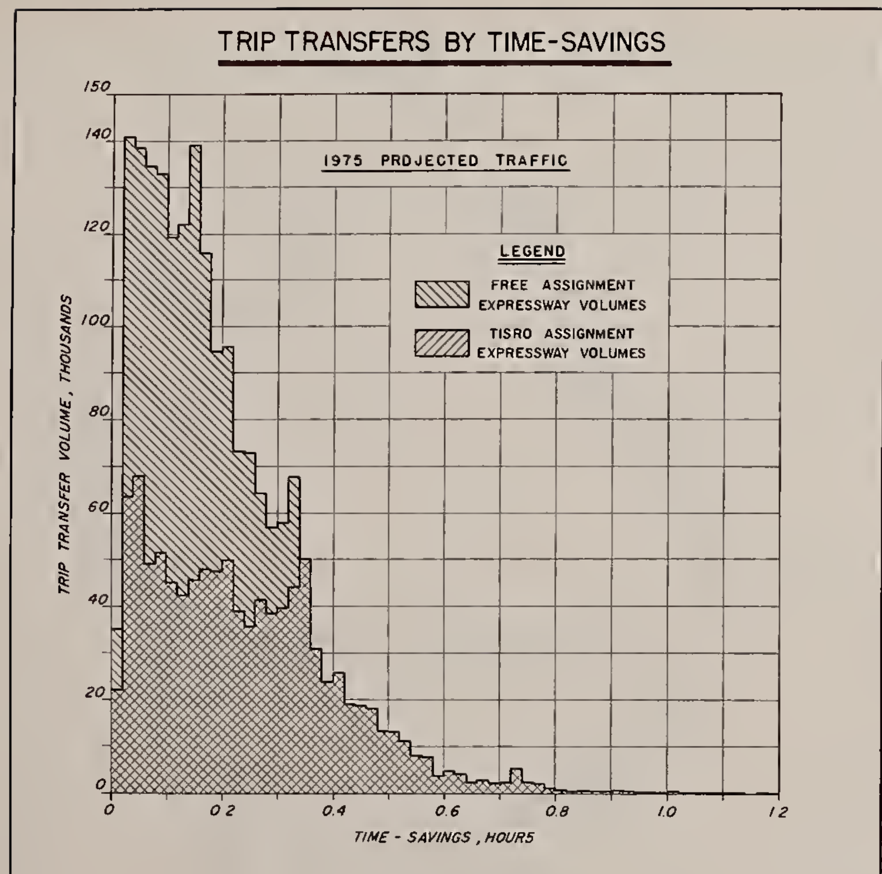


Exhibit T-29

street network exclusive of the expressways. It may be noted that all trip transfers having a time-saving of 0.36 hours (21.6 minutes) or greater are assigned to the expressways; these comprise a volume of 222,973 trips per day. Of those trip transfers having potential time-savings of one to about twenty minutes, from one-third to two-thirds are assigned to the expressways, respectively, for an additional volume of 818,306 trips per day. A summary of assignments of 1975 traffic appears in Table T-VI. The total number of trip transfers in the Standard Metropolitan Area matrix is 66,677 (comprising 3,745,988 trips per day in 1975), including 231 intra-zone transfers (comprising 911,963 trips per day in 1975) which are not assigned to the network by the assignment model. The remaining 66,454 interzonal transfers include 16,948 external station-to-zone transfers and 49,506 zone-to-zone transfers. Of these external station-to-zone and interzonal transfers, about 5,000 have no quicker path by the expressway route, and are therefore assigned to the street network only. The remainder are loaded under free assignment to the expressway-plus-street paths. Under TISRO assignment, however, those which are excluded from the expressways because of the capacity restraints are reassigned to the street network. These transfers, together with the transfers which have no quicker expressway path, make up the TISRO street-assigned trips.

Exhibit T-30 shows the assignment of the 1959 computed trip transfer matrix volumes to the 1975 Network 3 as related to time-savings. This assignment indicates the manner in which the Expressway System would be used, under the TISRO hypothesis, if it existed at the present time. Since a volume of only 132,307 trips per day in 1959 saves 0.36 hours or more by the Expressway System, as compared with 222,973 trips per day in 1975 with the same time-savings, a greater proportion of trips with lesser time-savings are assigned to the expressways in 1959 than are assigned in 1975, in order to utilize the capacity stipulated for each expressway link to the fullest extent compatible with the trip transfer volume matrix. Thus, for 1959 all transfers with time-savings greater than 0.28 hours (16.8 minutes), a volume of 282,625 trips per day, are assigned to the expressways, and of those with potential time-savings less than 0.28 hours, an additional volume of 663,282 trips per day are assigned to the expressways. Table T-VI itemizes the assignment of 1959 traffic to the Expressway System.

The volume of both 1959 and 1975 expressway assigned trips, in terms of percentage of all trip desires, falls within the range (27% to 58%) indicated by Smith [60] as the probable extent of future expressway usage in urban areas. The proposed Expressway System, consisting of eight-lane expressways, is adequate for only a comparatively small part of the total of all future potential desires, and as a result, the ratio of trips per day using the expressway to total trips per day in the Boston Metropolitan Area is at the low end of that range. The TISRO assignments of both 1959 and 1975 traffic to each individual expressway of Network 3 are illustrated in Exhibit T-31.

A critical link is defined as that link on a given expressway for which the free assignment desire is in the maximum range and the TISRO assigned volume equals the stipulated design capacity. The critical link for the 1975 assignments on each radial expressway is the section adjacent to the Inner Belt. Critical links also occur on the Central Artery between the Mystic River Bridge and the Sumner Tunnel, and between the interchange with the Massachusetts Turnpike near South Station and the Southeast Expressway. The critical links restrict the full usage of other portions of the system, in some cases to a volume far less than capacity. In particular, the section of the Inner Belt between the Southwest and Southeast Expressways has been assigned a two-way total volume of 62,000, or only 38% of its stipulated design capacity. Reference to Exhibit T-31, however, reveals that the adjacent section of the Central Artery is carrying its full design capacity, as is the adjacent section of the Southeast Expressway. It is evident that under *any* rational assignment procedure no more traffic may be assigned to this Inner Belt section without

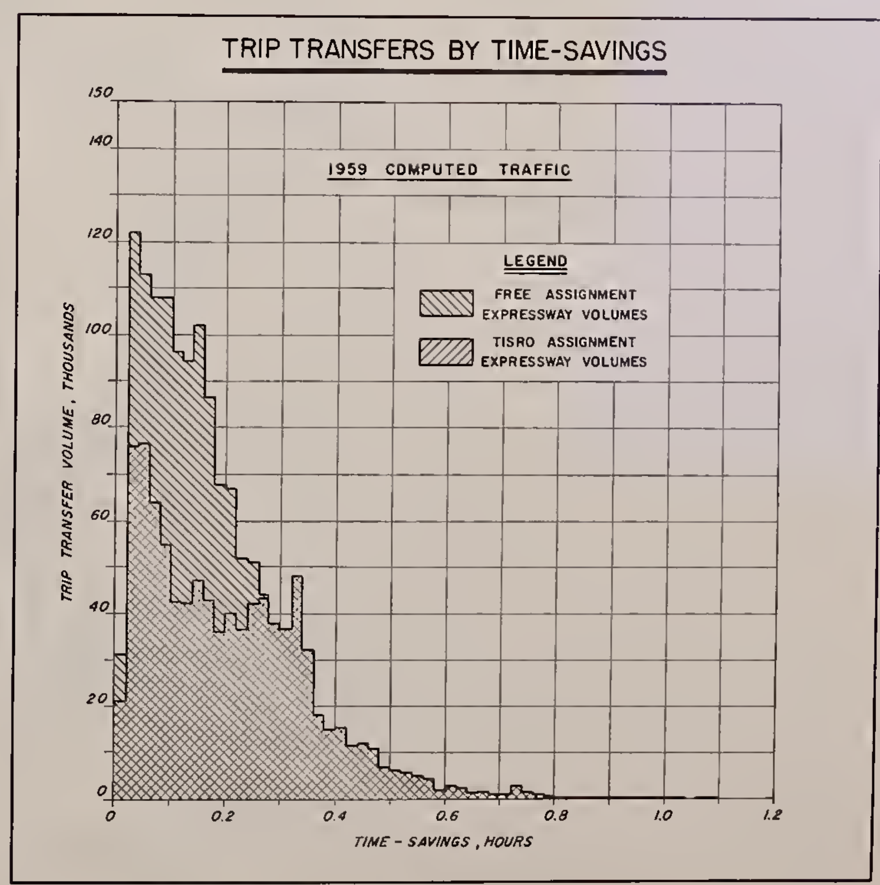


Exhibit T-30

the provision of additional capacity parallel to these other facilities. This matter is further discussed in Section 4.

At each junction of a radial expressway with the Inner Belt, the radial is carrying a traffic load equal to its design capacity, which without the provision of additional lanes on the radial, precludes the use of adjacent portions of the Inner Belt to full capacity. It is evident that the volumes assigned to these less-than-capacity sections might be increased by changing the stipulated values of K, D and T. The values used for K, D and T resulted, as noted earlier herein, in a capacity of 162,000 vehicles per day for the Inner Belt, and of 132,000 vehicles per day for the proposed radial expressways at their junctions with the Inner Belt, although the number of lanes are identical. However, since empirical data collected for the existing expressways indicates that the design hour volume in each direction on the Inner Belt will be more nearly equal than the design hour volume on the radials, and that the radials will carry a somewhat larger proportion of their daily traffic in the design hour than will the Inner Belt, this difference in capacity as noted above is reasonable. The selected values of K and D are based on these conclusions and projections of future expressway use, and it is considered that any revision of these values would not be warranted.

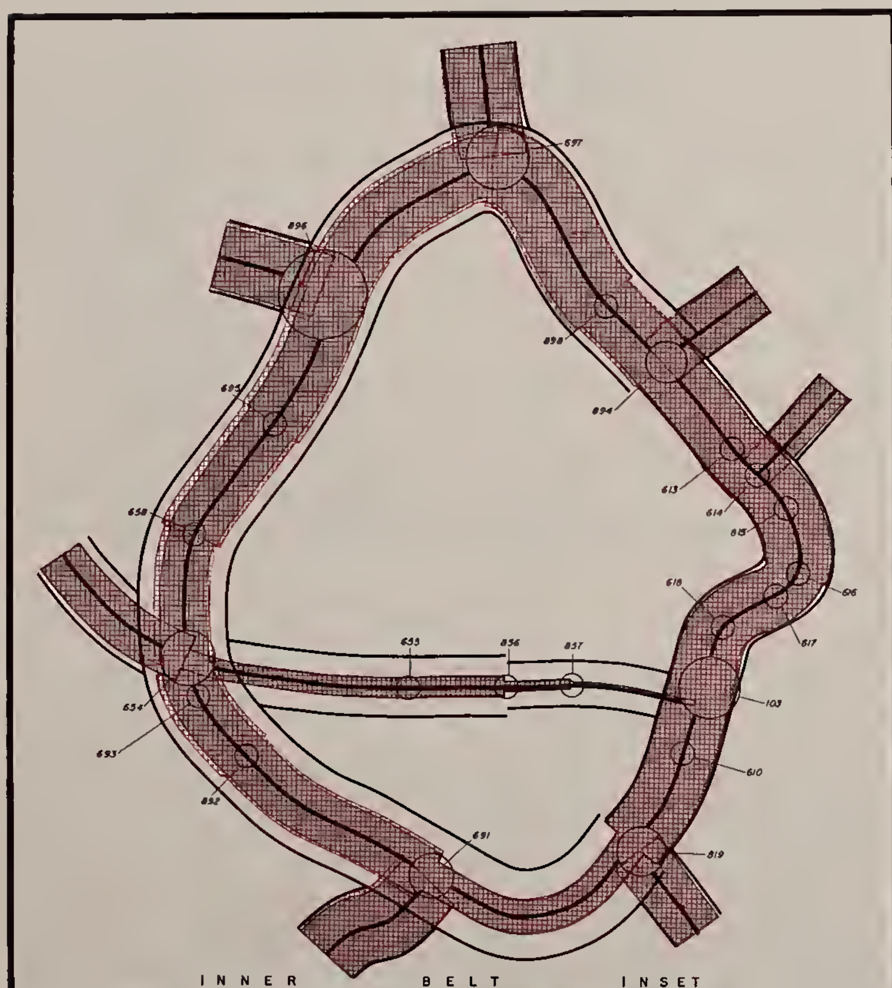
It is also evident that the value of lane capacity used for design is less than volumes which have been measured on existing urban expressways. However, such higher values could not be used in design, nor could the fact that the number of lanes actually used for travel is greater than the number of lanes designed for travel be considered in the determination of design capacities. The values adopted and used for this Study are considered sound, and the numerical solutions obtained are reasonable and may be used as an important guide in understanding the complexity of traffic movements on this Expressway System of pre-determined capacity.

An indication of the results which might be obtained by increasing the capacity of the radial expressway sections adjacent to the Inner Belt is, by coincidence, available in the results of the TISRO assignment to the Massachusetts Turnpike. At the junction of the Inner Belt and the Turnpike, the Inner Belt capacity remains, as elsewhere, at 162,000 vehicles per day, while the Turnpike stipulated capacity is 108,000 vehicles per day. At the approach to the Inner Belt, however, the TISRO assignment to the Turnpike is 87,500, or only 81% of capacity, while the Inner Belt is carrying an assigned volume of about 115,000 vehicles per day, or 71% of capacity. In this case the six-lane section of the Turnpike between Interchange 99 at West Newton and Interchange 100 at Newton Corner is assigned the full capacity volume of 80,000 vehicles per day, thus precluding any further assignment to the section of the Turnpike adjacent to the Inner Belt, except that 7,500 shorter trips make use of the section adjacent to the Inner Belt. If, by some acceptable rationalization, the design capacities on the proposed radial expressways at their junction with the Inner Belt were to be increased to equal that of the Inner Belt, it would probably be found that a similar situation would develop. An expressway section farther out on the radial could be carrying capacity traffic, while that section adjacent to the Inner Belt could be below capacity. It is generally true that the per-lane efficiency of use of roadways wider than four lanes in each direction drops off sharply. The width of roadways contemplated in these areas is four lanes; alteration of the values of K and D in a manner to indicate a need for more than four lanes would thus be self-defeating.

With these and related considerations in mind, a preliminary analysis was made of the TISRO assignment of traffic to the three networks presented to the computer. It was confirmed that these assignments would be entirely adequate for use as a basis upon which the design assignments could be established. It is evident that valid rational procedures other than the TISRO method could be developed, such as requiring that alternate expressway paths be used as well as the alternate street path, but analysis of the results of the TISRO assignments indicates that such refinements would, with regard to the Expressway System, change only the *nature* of the transfers assigned to the system, and not materially affect the *volumes* assigned to either the expressways or the ramps in that portion of the system involved in this Study.

TABLE T-VI
ASSIGNMENTS TO 1975 HIGHWAY NETWORK

Type of Traffic	1959 Computed Traffic Volume	% of Total	% of Interzonal	1975 Projected Traffic Volume	% of Total	% of Interzonal
All Trips	2,849,695	100%	—	3,745,988	100%	—
Intra-zonal Trips	884,000	31%	--	911,963	24%	—
Inter-zonal Trips	1,965,695	69%	100%	2,834,025	76%	100%
Street-Alone Trips	539,554	19%	27%	902,273	24%	32%
Free-Assignment Expressway Trips	1,426,141	50%	72%	1,931,752	52%	68%
TISRO-Assignment Expressway Trips	945,907	33%	48%	1,041,279	28%	37%
Expressway-Excluded Trips	480,234	17%	24%	890,473	24%	31%
Street-Alone Trips	539,554	19%	27%	902,273	24%	32%
TISRO Street-Assigned Trips	1,019,788	36%	52%	1,792,746	48%	63%



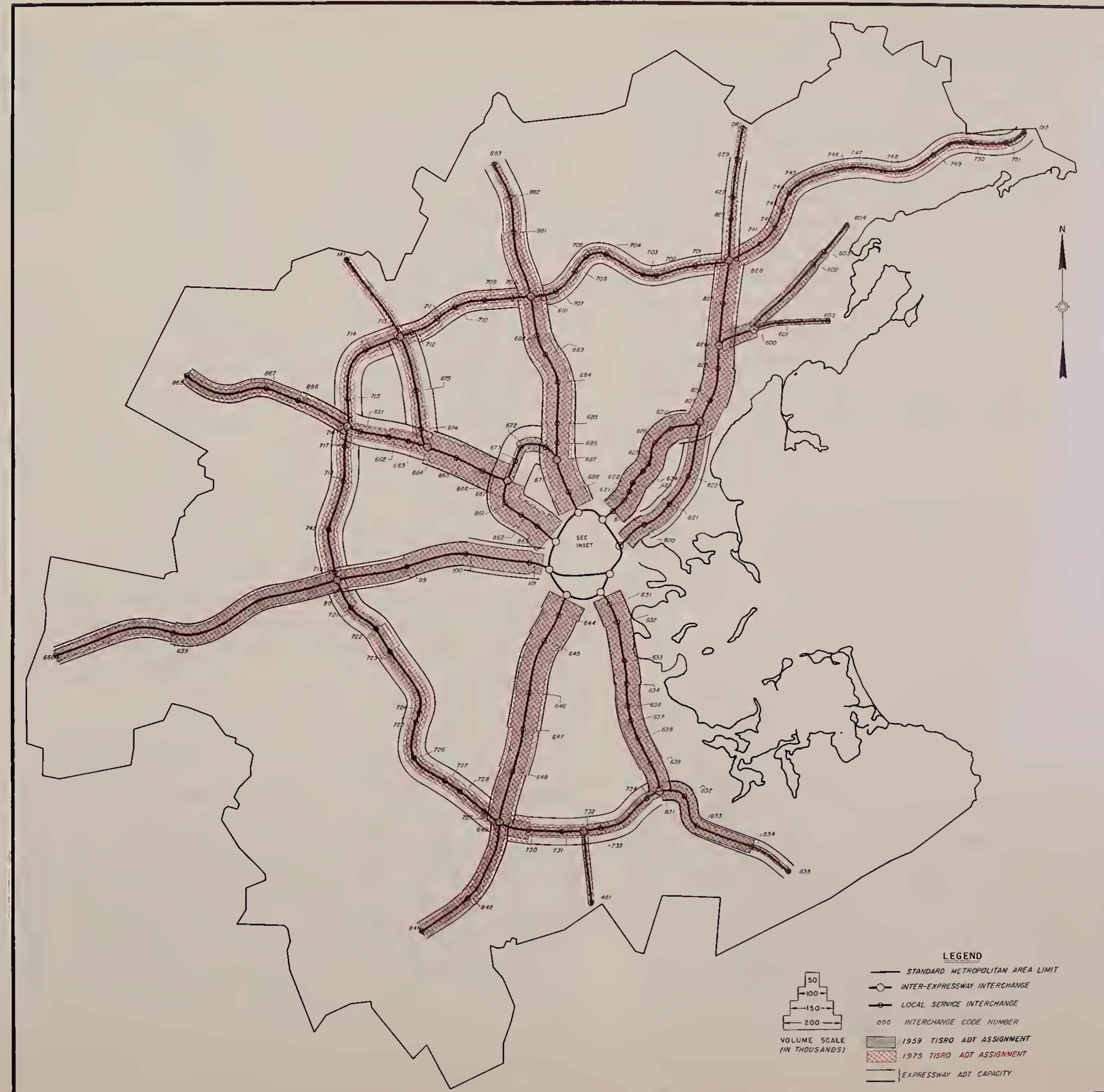


Exhibit T-31

BASE YEAR AND DESIGN YEAR TISRO ASSIGNMENTS

SECTION 4 – DESIGN ASSIGNMENTS

INTRODUCTION

The TISRO assignments as obtained from the computer operations pertained specifically to the three expressway networks which were selected for electronic computation. As previously noted, these networks were chosen on the basis that interpolation of the TISRO assignments would yield traffic volumes applicable to any of the alternative locations studied. Furthermore, in order to arrive at values of assigned traffic for design purposes, three factors were given consideration. First, the general location and relative amount of local service provided by the networks had to be maintained. Second, in some cases, the TISRO assignments to ramps required refinement in order to obtain a valid design of the local interchanges. Third, the resulting average daily traffic had to be converted to design hour volumes.

FACTORS IN DETERMINATION OF ASSIGNED TRAFFIC VOLUMES

GENERAL LOCATION AND AMOUNT OF LOCAL SERVICE

The general location and extent of the expressway networks selected was predetermined by the terminal control points, the corridors of location, and the scope of this Study. The relative amount of local service provided by each network was derived from basic designs of alternative locations so as to obtain the optimum local service for the recommended basic design. Substantial departures in the recommended basic design, from either the general location or the amount of local service, would require a completely revised set of assigned volumes throughout the network. The final assignments to the Expressway System were therefore based on the original assumptions as to the number, location and capacities of the expressways, which served as a basis for the networks used in the TISRO assignments, even though these assignments indicated the necessity for augmented expressway capacity.

REFINEMENT OF TISRO RAMP ASSIGNMENTS

The TISRO program permitted the assignment of unrestricted ramp volumes up to the limit imposed by the design capacity available on the expressway. Analysis of the TISRO assignments to the three networks indicated that the ramp assignments at a limited number of proposed locations were substantially higher than those generally accepted for single-lane ramp design. Contributing volumes to and from nodes adjacent to ramp locations were sub-divided in order to yield ramp design assignments compatible with the expressway design assignments. The output from computer reports 5, 6 and 7 provided the means for the refinement of ramp loadings. These reports contain full details of every trip-transfer in the system, as follows:

Report 5 — Lists of expressway-assigned positive time saving transfers by origin and destination.

Report 6 — Lists of trip transfers in which the links of each minimum path are presented in order of use.

Report 7 — Lists of the incremental load on each link from each trip transfer.

Zone volumes were extracted by means of reports 5, 6 and 7, and then subdivided and proportioned into the sectors comprising the zone on the basis of the land use and population of each sector. These sector volumes were then manually re-assigned to serve as the basis for determinations of average daily traffic volumes for location and design of the various interchanges.

AVERAGE DAILY TRAFFIC

For each expressway studied, the basic design which provided the most favorable features of location, cost and potential traffic service was selected and assignments were made to the local interchanges, which in turn were evaluated on the basis of the optimum desired traffic service. Necessary adjustments, where practicable, were made to the basic design without compromising the expressway design standards. At some locations, especially along the Inner Belt, the traffic potential to a particular area was greater than the design volume allowable on a single-lane ramp. In these cases, a higher type of interchange design was considered, but it was found that this treatment would induce greater traffic volumes than could be accommodated by the local street system. The recommended solutions included additional single-lane ramps to provide the necessary traffic service. After modifications to the basic design were incorporated to provide optimum traffic service, final assignments to the Recommended and Alternate Locations were made, resulting in the average daily traffic (ADT) volumes shown on the traffic schematic diagrams and the Basic Design Exhibits.

DESIGN HOUR VOLUMES

Determination of the ADT volumes for each segment of the expressways and for the ramps was followed by computation of the design hour volumes (DHV), which are dependent upon ADT volumes. This computation consisted of two parts:

a. Calculation of expressway DHV's,

b. Deriving from empirical data a relationship between expressway and ramp volume for use in calculating ramp DHV's.

AASHO Policy indicates that for urban areas, the DHV, or thirtieth highest hourly volume of the year, is the equivalent of the normal daily peak hourly volume. It has been the practice to vary the ratio of one-way to two-way traffic in such a way as to yield a continuity of the resulting values of DHV, as illustrated in Figure C-6 of AASHO Policy.[51] Thus the expressway DHV, on a section approaching an off-ramp, minus the off-ramp DHV equals expressway DHV beyond the off-ramp; this plus on-ramp DHV equals expressway DHV beyond the on-ramp, and so on, along the length of the expressway. This method, however, disregards two known factors. First, it is known that the peak hour does not occur at the same time either for all sections along the length of an expressway, or on each ramp. This factor negates the validity of such arithmetic continuity. The *time* of occurrence of the peak volume, of course, has no bearing on the volumes for which the expressway sections and ramps must be designed, although it may affect detailed analyses of weaving movement. Secondly, it is also known, in general, that with symmetrical ramp design and in the absence of any adjacent large traffic generator with unusual hours of attendance, if a given ramp carries a certain volume in the A.M. peak period, the volume on the corresponding ramp in the opposite direction in the P.M. peak period will be closely

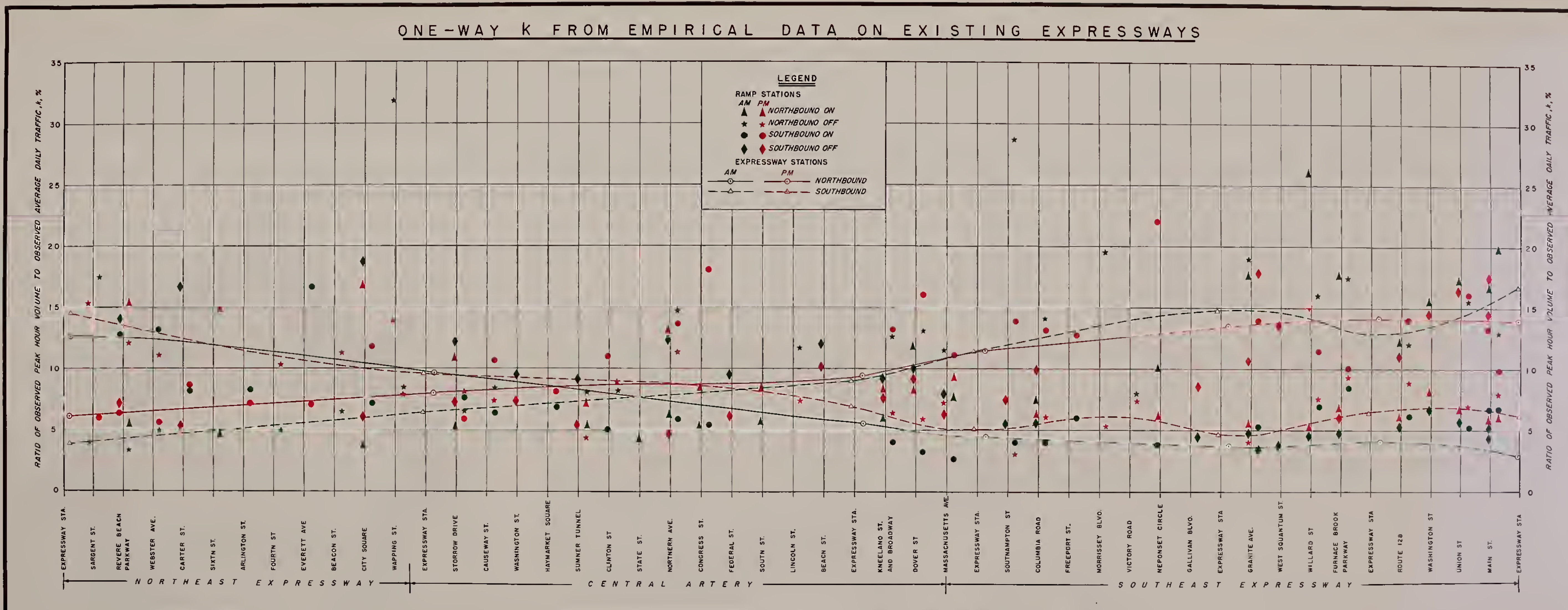


Exhibit T-32

equivalent, unlike the example of Figure C-6 of AASHO Policy.

Considering these factors, it was decided to investigate the DHV relationships mentioned above, with the purpose of basing DHV calculations on valid empirical data rather than attempting artificially to make the DHV volumes yield the customary continuity of values. This investigation was prompted by the suggestion, noted in AASHO Policy,[51] as to the need for such research, as well as by the necessity of applying a rational and consistent method to arrive at a DHV from the assigned ADT volumes for each element of the Expressway System.

EXPRESSWAY DESIGN HOUR VOLUMES

The ADT capacity restrictions of the TISRO assignments, as noted in Section 3, were derived from projected values of K, D, and T judged appropriate for each portion of the Expressway System on the basis of evidence available from the Department regarding these values for existing expressways. With rational values of K assigned as described in Section 3, it was necessary only to reverse the computation to yield one-way DHV from the design ADT. On the basis that bidirectional equality of average daily traffic exists, it follows that the ratio k of one-way design hourly expressway volume to one-way ADT may be derived thus:

Let v = directional design hourly volume, DDHV,
V = two-way design hourly volume, DHV,
D = ratio of DDHV to DHV,
a = directional average daily traffic, DADT,
A = two-way average daily traffic, ADT,
k = ratio of DDHV to DADT,
K = ratio of DHV to ADT.

Then the two-way design hourly volume, V, is identically equal to the directional design hourly volume, v, divided by the ratio D:

$$V = \frac{v}{D}$$

and

$$A = \frac{V}{K} = \frac{v}{KD}$$

But on the basis noted above,

$$a = \tfrac{1}{2}A = \tfrac{1}{2}\,\frac{v}{KD}$$

and thus

$$k = \frac{v}{a} = 2\,KD$$

The directional DHV for each expressway segment is therefore determined by multiplying the directional ADT by the value k, which is equal to 2KD.

RAMP DESIGN HOUR VOLUMES

For the purpose of determining the relationship of ramp DHV to ramp ADT, an investigation was made of existing expressway ramp usage. Field data regarding traffic volumes on existing expressways and ramps were obtained from the Department. From this data, values for one-way ADT, directional peak-hour volume and directional counter-peak volume, as defined below, were calculated for each of the one hundred ramps in the existing system (Northeast Expressway, Central Artery, and Southeast Expressway), including the interchange ramps of direct connectors. As expected, peak-hour flow did not occur at the same time for all parts of the system. Values of k were then found for each of the hourly flows, and a plot was made of expressway and ramp k against location, in order of geographic occurrence, for both A.M. and P.M. hourly volumes, as shown in Exhibit T-32. By inspection it was evident that a correlation existed between expressway k and ramp k, as suggested by the trend lines of Exhibit T-32. Further examination of the field data yielded the conclusion that the variations of traffic flow on both expressway and ramps were sufficiently wide-ranging that if the nature of the relationship could be determined, the results could be satisfactorily applied to any combination of the expressway and ramp ADT's which had been assigned to the expressways of this Study. For further investigation the hourly data were divided into two primary categories depending upon type of ramp, and three secondary categories depending upon flow conditions, as follows:

On-Ramps: Peak Flow, Counter-Peak Flow, and Diametral Flow.

Off-Ramps: Peak Flow, Counter-Peak Flow, and Diametral Flow.

Peak flow is defined as the maximum one-way hourly volume that occurs each morning and afternoon. Counter-peak flow is that which occurs in the opposite direction at the same time as peak flow. Diametral flow is defined as that peak flow which occurs in a section of a traffic facility where the volumes of the movement in each direction are essentially equal, or where the ratio, D, is equal to 50%. That part of the existing expressway system carrying diametral flow was found to be the Central Artery from Charlestown to its interchange with the Southeast Expressway.

The problem then required determination of a functional relationship between the one-way ADT on that portion of the expressway associated with a ramp, the ramp ADT, the peak or counter-peak expressway hourly volume, and the ramp peak hourly volume. Using the symbols previously noted, and the subscripts R for ramp and E for expressway, the relationship would take the form:

$$v_R = f\,(a_R, a_E, v_E)$$

TABLE T-VII
CORRELATING FACTORS DERIVED FOR RAMP-USE FUNCTION

Ramp Type	Flow Type	Multiplier, Φ	Exponent, n
On	Peak	1.08	0.009
On	Caunterpeak	3.46	1.866
On	Diametral	3.28	1.876
Off	Peak	1.49	1.948
Off	Caunterpeak	1.95	1.945
Off	Diametral	5.40	1.826

Rationally, as ramp ADT increases, the proportion of ADT in the peak hour decreases, or, the value of ramp one-way k varies inversely as the ramp ADT:

$$k_R \sim \frac{1}{a_R}$$

It may also be reasoned that, as the proportion of expressway DADT occurring in the peak hour increases, the ramp hourly volume in that time period will also increase:

$$v_R \sim k_E$$

A further rationalization is that, as the ramp ADT increases, the ramp peak hourly volume will also increase:

$$v_R \sim a_R$$

A logical combination of these dependencies was formulated:

$$v_R = \Phi\,\frac{v_E}{a_E a_R^{\,n}}$$

in which the previous notations are used, and

Φ = a multiplying factor,

n = an exponent, which might be negative, to account for the fact that a_R enters these dependencies in different methods of variation.

The field data was then used to determine those values of Φ and n, for each of the categories, which would result in the greatest correlation between the left and right sides of the equation, by converting the equation to logarithmic form and applying the least-squares regression method. The computations were made on an IBM 709 electronic computer yielding values for Φ and n as shown in Table T-VII. Graphs were then prepared for both on-ramps and off-ramps on the basis of these values, as shown in Exhibit T-33.

These graphs are used by entering on the abscissa with the assigned ramp ADT (as shown in the Traffic Schematic Diagrams, Exhibits T-34 through T-39), reading upward to the curve for the

associated expressway k (computed, as described previously, from the relevant K and D values shown in Exhibit T-28) and then reading left to the corresponding ramp k. As an example, as shown on Exhibit T-33 for an on-ramp ADT of 3000 vehicles per day, and a k of 7% on the adjacent expressway section, the ramp k would be 8.4%. The value of k_R is then multiplied by the ramp ADT to arrive at the required ramp DHV. Thus, in the example, the ramp DHV would be 252 vehicles per hour.

While it is recognized that the work involved in correlating the empirical data for preparation of these graphs by no means exhausts the possibilities for research on the relationships between ramp volumes and expressway volumes, it does result in a consistent, realistic approach to the determination of ramp design hour volumes for the purpose of this Study. These DHV values appear with the corresponding ADT volumes on the traffic schematic diagrams and the Basic Design Exhibits.

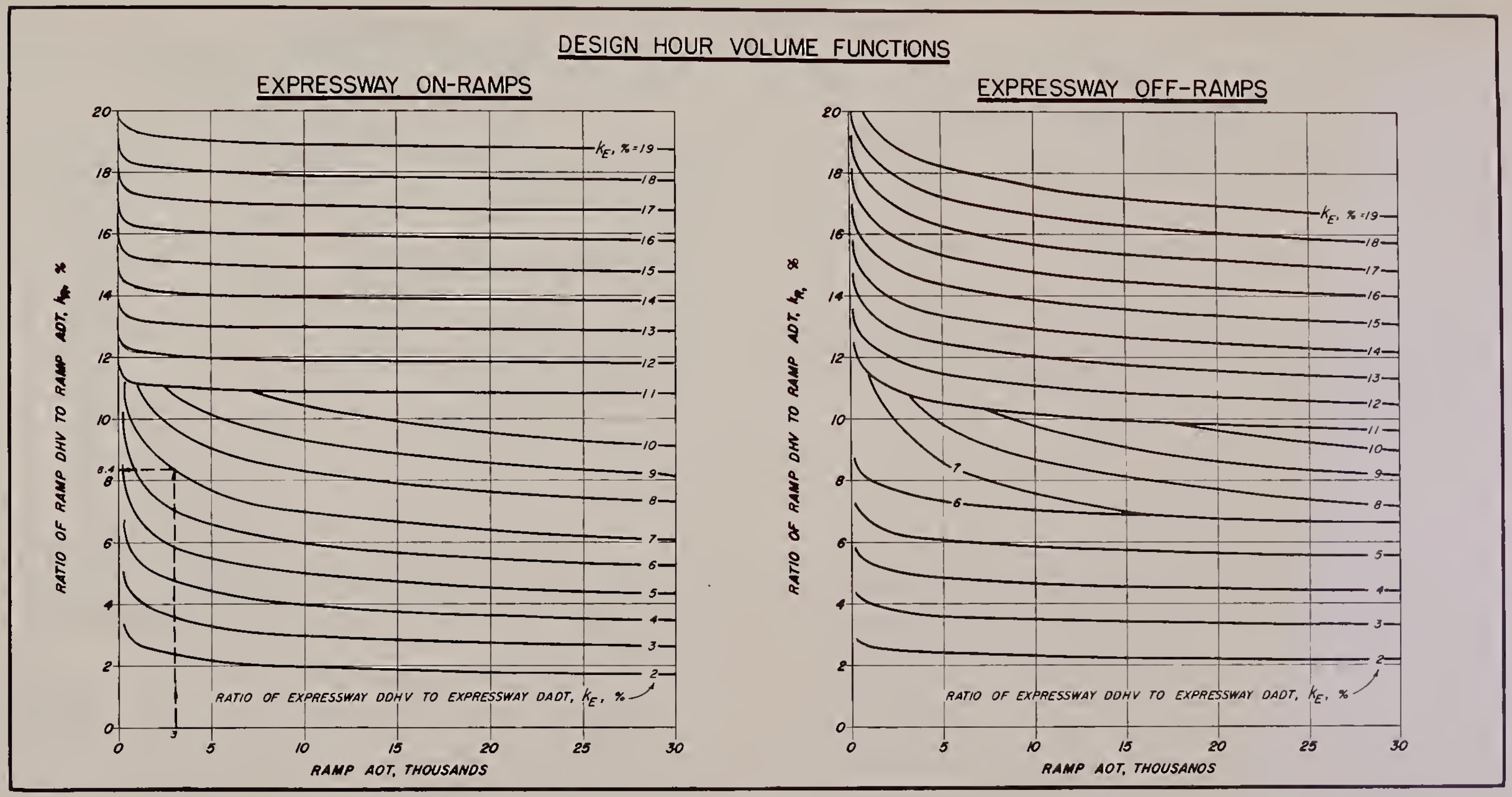


Exhibit T-33

ASSIGNED TRAFFIC VOLUMES

The traffic volumes determined by the procedures described above are for the design year 1975; however, the *desire* to use these expressway facilities is beyond the practical limits of design, and it is therefore anticipated that on most sections of the Expressway System the volumes indicated would occur now if the proposed facilities were in actual use.

INNER BELT

GENERAL

Table T-VIII summarizes the relationship of design capacities to the TISRO and free assignments for the Inner Belt, the Central Artery, and the adjacent sections of the radial expressways. The assigned ADT volume on the section of the Inner Belt between the Southeast Expressway and the Southwest Expressway is significantly less than the recommended eight-lane design capacity, even though the free assignment desire is far greater. This condition is the result of the assignment of capacity volumes to those sections of the Expressway System adjacent to this underloaded section, thus preventing more traffic from entering this section of the Inner Belt. Therefore, referring to the above Table, it will be noted that only 38% of the design capacity is assigned to this section, in which case the question arises as to the practicability of constructing eight lanes instead of the four lanes normally required for the volumes shown.

Under these circumstances, it must be considered that the conditions causing this sharp drop in volume in this particular section may be improved in the future by the introduction of other facilities such as:

a. Improvements or separate facility to increase the capacity of the Central Artery.
b. Improvements to increase the capacities of both the Southeast and Southwest Expressways prior to their connection with the Inner Belt.
c. Additional access ramps.
d. Cross-town expressway between the Southwest and Northern Expressways.

Provisions should be made therefore in the design of this critical section to provide for these eventualities even though the presently-assigned volumes seemingly warrant only a four-lane facility initially. In addition, the desirability of planning for a continuous eight-lane Inner Belt facility cannot be questioned. Accordingly, the Basic Design Exhibits presented herein provide for this continuity of design and it is so recommended.

RECOMMENDED LOCATION

The volumes assigned to the Recommended Location, which follows the Ruggles Street alignment, are shown on Exhibit T-34. On Exhibits T-35, T-36, and T-37 are the volumes assigned to

the direct-connector interchanges of the Recommended Location with the radial expressways.

The 1975 assigned volumes reach capacity between the Charles River and Massachusetts Avenue, Cambridge. The 1975 ADT assignments to the various sections of the Recommended Location are as follows:

a. 67,000 vehicles per day: Southeast Expressway to Southwest Expressway.
b. 104,000 vehicles per day: Southwest Expressway to ramps in the Fenway area.
c. 138,000 vehicles per day: Fenway area to connections to the Massachusetts Turnpike.
d. 161,000 vehicles per day: Massachusetts Turnpike to ramps serving the Massachusetts Avenue area of Cambridge.
e. 134,000 vehicles per day: Massachusetts Avenue, Cambridge, to Northwest Expressway.
f. 130,000 vehicles per day: Northwest Expressway to Northern Expressway.
g. 134,000 vehicles per day: Northern Expressway to Prison Point Bridge Interchange.
h. 115,000 vehicles per day: Prison Point Bridge Interchange to present terminus of the Central Artery in Charlestown.

Four lanes in each direction are recommended for the Inner Belt between direct-connector interchanges. The recommended lane balance at the direct-connector interchanges provides three lanes in each direction for the Inner Belt through-traffic and two lanes in each direction for the direct connectors to each radial expressway.

Alternate Designs for parts of the Recommended Location occur at:

a. The direct-connector interchange with the Southwest Expressway.
b. The vicinity of the Boston Museum of Fine Arts.
c. The Charles River crossing.

Traffic assignments for the Recommended Location and for the above Alternate Designs are shown on the Basic Design Exhibits; these assignments indicate the minor effects caused by variations in the location of the local interchanges. However, each variation did produce changes in the volume assigned to individual ramps which in turn were considered in the design of these ramps. Assignments to Alternate Design I in the vicinity of the Museum of Fine Arts require a two-lane on-ramp, and to provide the proper lane balance, a northbound lane was added to the Inner Belt between this ramp entrance and the Massachusetts Turnpike interchange.

TABLE T-VIII
INNER BELT TRAFFIC ASSIGNMENTS

Description	From	To	No. of Lanes	TISRO Average Daily Traffic as % of Capacity Available	TISRO Average Daily Traffic as % of Free Assignment Desire	Capacity as % of Free Assignment Desire
Northeast Expressway	*		6	100%	48%	48%
Central Artery	NE	Tunnel	6	100%	28%	28%
Sumner Tunnel	*		4	100%	44%	44%
Central Artery	Tunnel	SE	6	100%	30%	30%
Southeast Expressway	*		6	100%	30%	30%
Inner Belt	SE	SW	8	38%	23%	61%
Southwest Expressway	*		8	100%	51%	51%
Inner Belt	SW	Tpke	8	69%	45%	65%
Inner Belt	Tpke	NW	8	80%	70%	87%
Northwest Expressway	*		8	97%	67%	69%
Inner Belt	NW	N	8	78%	58%	74%
Northern Expressway	*		8	100%	57%	57%
Inner Belt	N	NE	8	90%	48%	53%

*At interchange with the Inner Belt

ALTERNATE LOCATION

The traffic assignments to the Alternate Location south of the Charles River along the Tremont Street route are shown on the Basic Design Exhibits. The volumes for this location are very similar to those shown for the Recommended Location. To provide ramp service comparable to the Recommended Location, northbound on- and off-ramps between the Massachusetts Turnpike and the Southwest Expressway are closely spaced, due to the pattern of the existing arterial streets between the two locations. The traffic assignments to the Alternate Location north of the Charles River along the Grand Junction Branch of the New York Central Railroad are shown on the Basic Design Exhibits. Minor variations in the assigned volumes from those shown for the Recommended Location are apparent, and are due primarily to the differences in the ramp systems.

Exhibit T-34

DESIGN ASSIGNMENTS: INNER BELT

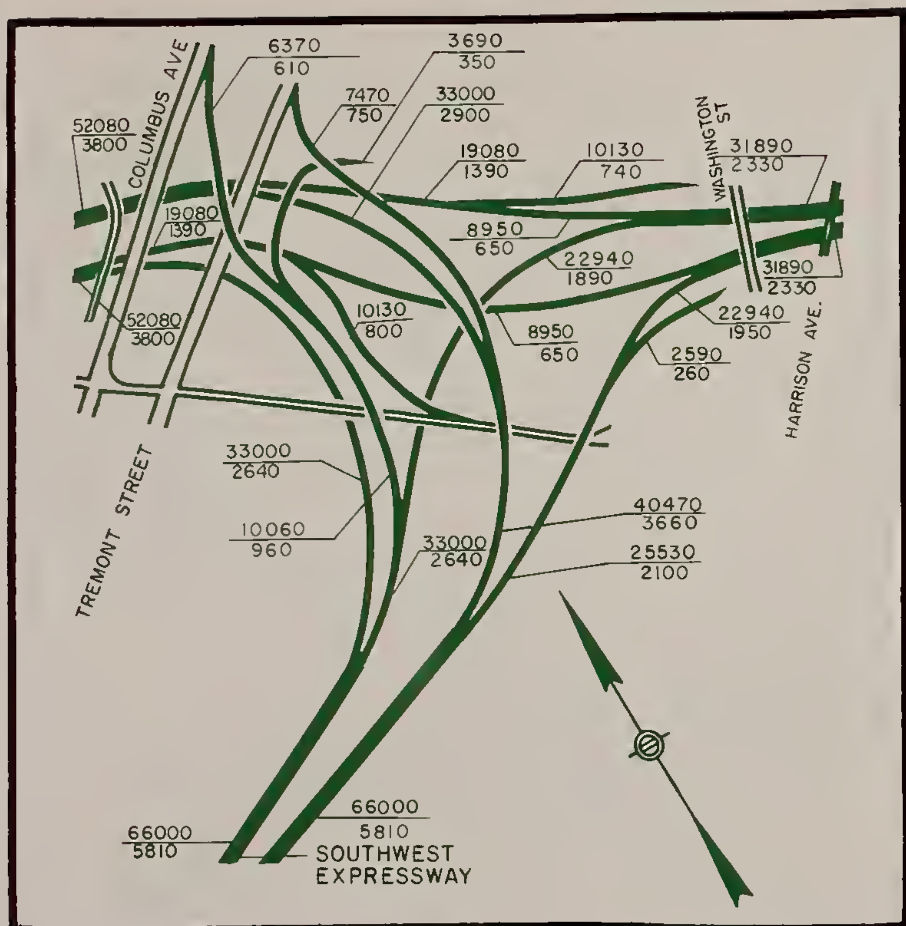


EXHIBIT T-35
INTERCHANGE DESIGN ASSIGNMENTS
INNER BELT AT SOUTHWEST EXPRESSWAY

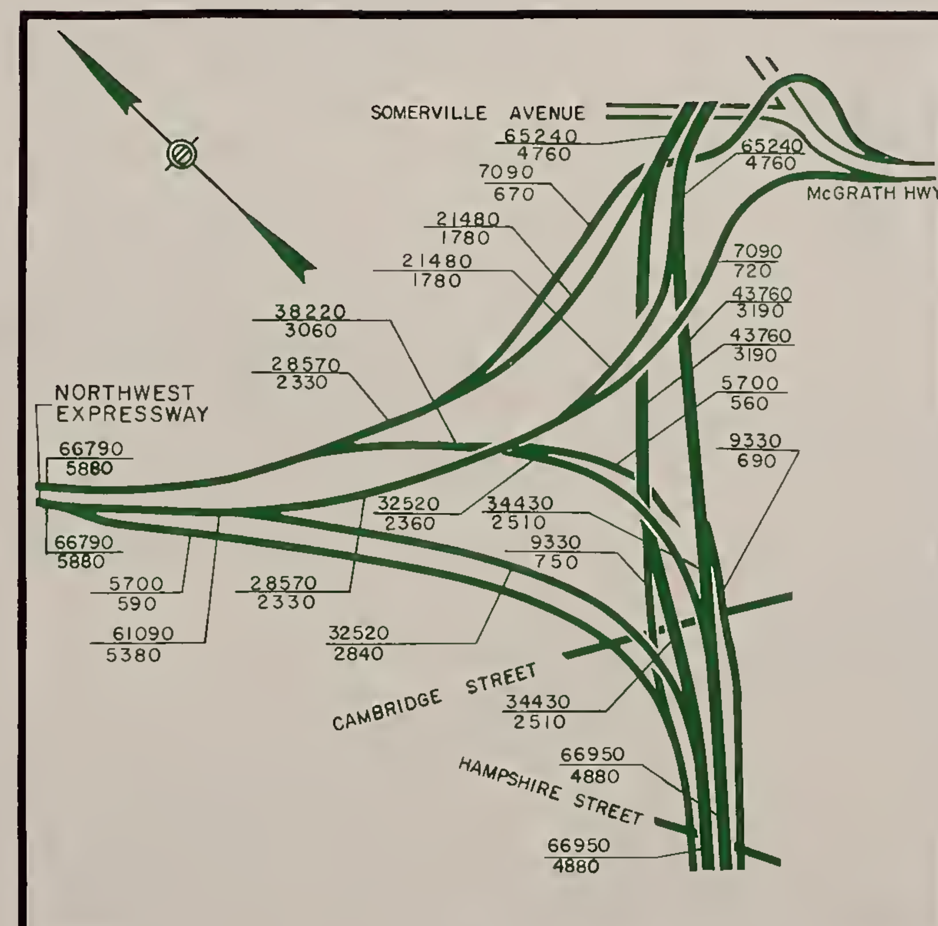


EXHIBIT T-36
INTERCHANGE DESIGN ASSIGNMENT
INNER BELT AT NORTHWEST EXPRESSWAY

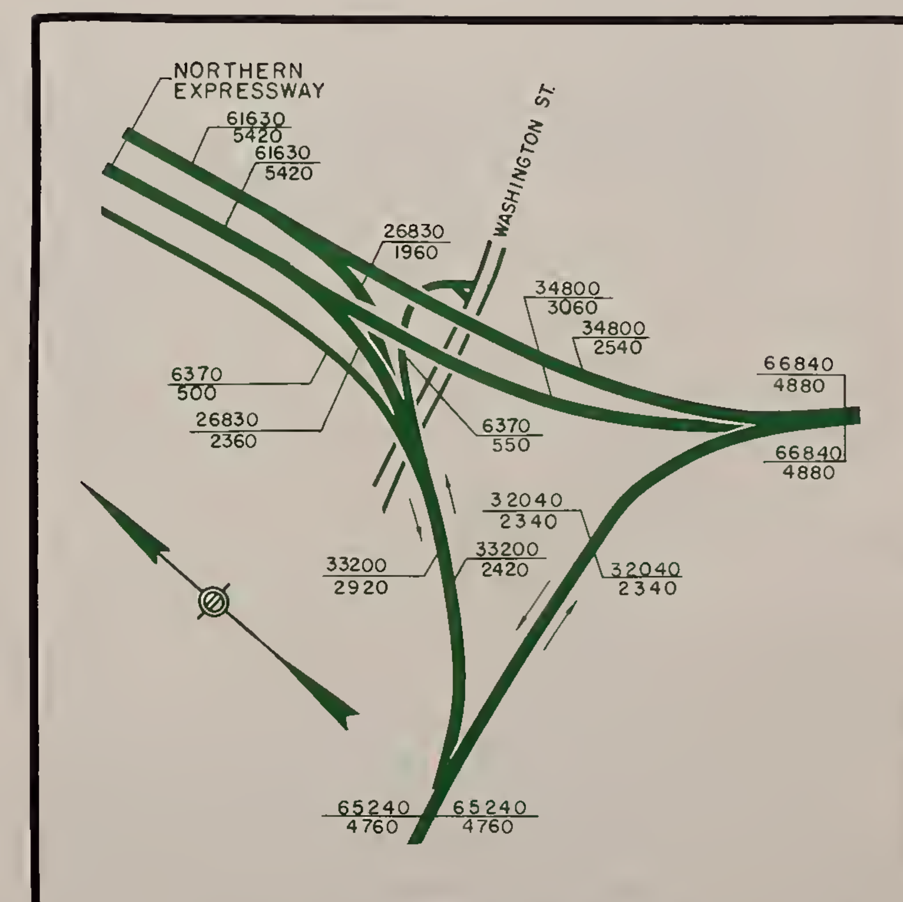


EXHIBIT T-37
INTERCHANGE DESIGN ASSIGNMENT
INNER BELT AT NORTHERN EXPRESSWAY

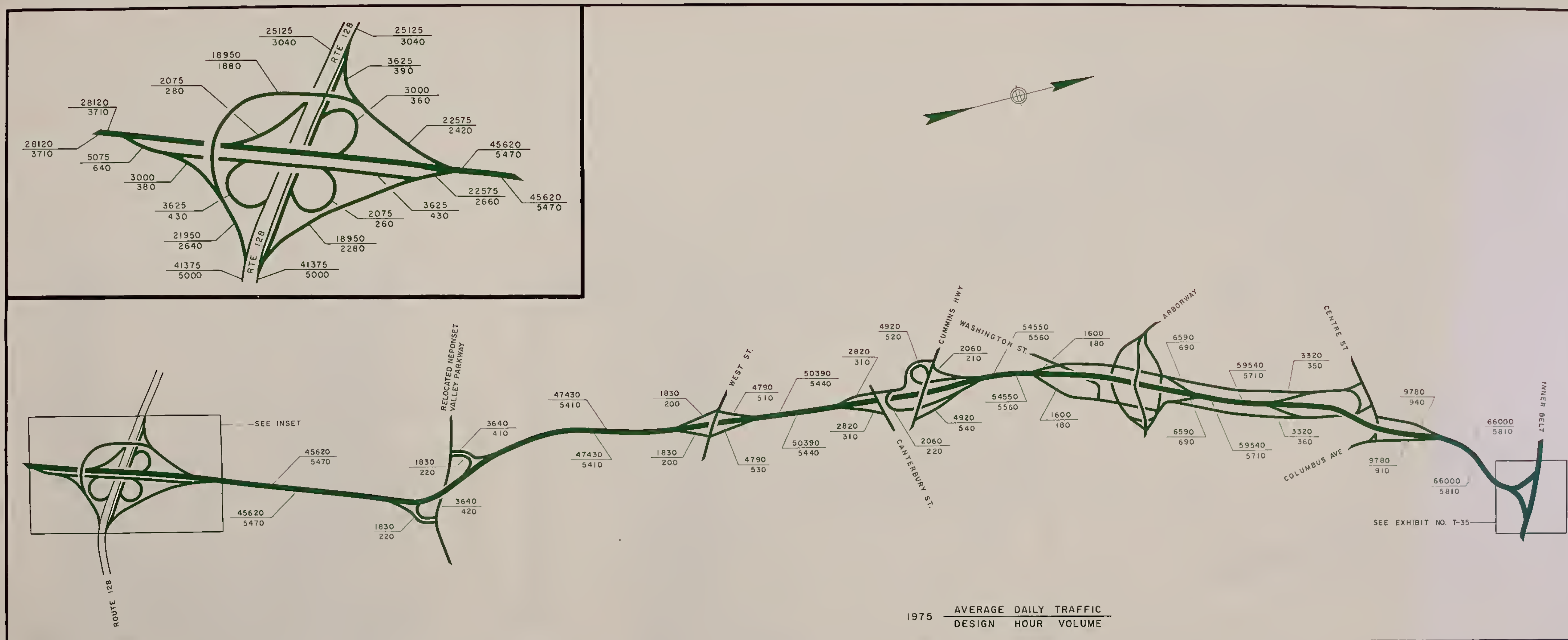


Exhibit T-38

DESIGN ASSIGNMENTS: SOUTHWEST EXPRESSWAY

SOUTHWEST EXPRESSWAY

RECOMMENDED LOCATION

The ADT volumes assigned to the Recommended Location are shown on Exhibit T-38. The heaviest volume, 132,000 vehicles in 1975, occurs just south of the interchange with the Inner Belt. The volumes decrease through the several interchanges to approximately 91,000 vehicles just north of the interchange with Route 128. However, the design hour volumes remain relatively constant, with only a minor reduction on the section between the Inner Belt and Route 128, due to the variable K, D, and T factors applied, as shown on Exhibit T-28. A minimum of four lanes in each direction is recommended throughout the design section for the Southwest Expressway. Extensive local improvements, including frontage roads, one-way streets and widening of local streets will be required at nearly all of the interchanges. A major part of the assigned expressway traffic originates south of Route 128. Of the total traffic assigned to the various interchanges between Route 128 and the Inner Belt, approximately two-thirds have destinations northerly of the Inner Belt, with the remaining one-third destined southerly for Route 128 or beyond. Traffic volumes for all movements at the Route 128 interchange are shown on Exhibit T-38. The major movements at this interchange are the through movements on the Southwest Expressway, and the movements between the north and east, which are approximately equal. The movements between the north and east, of approximately 19,000 vehicles each, require two-lane direct connectors.

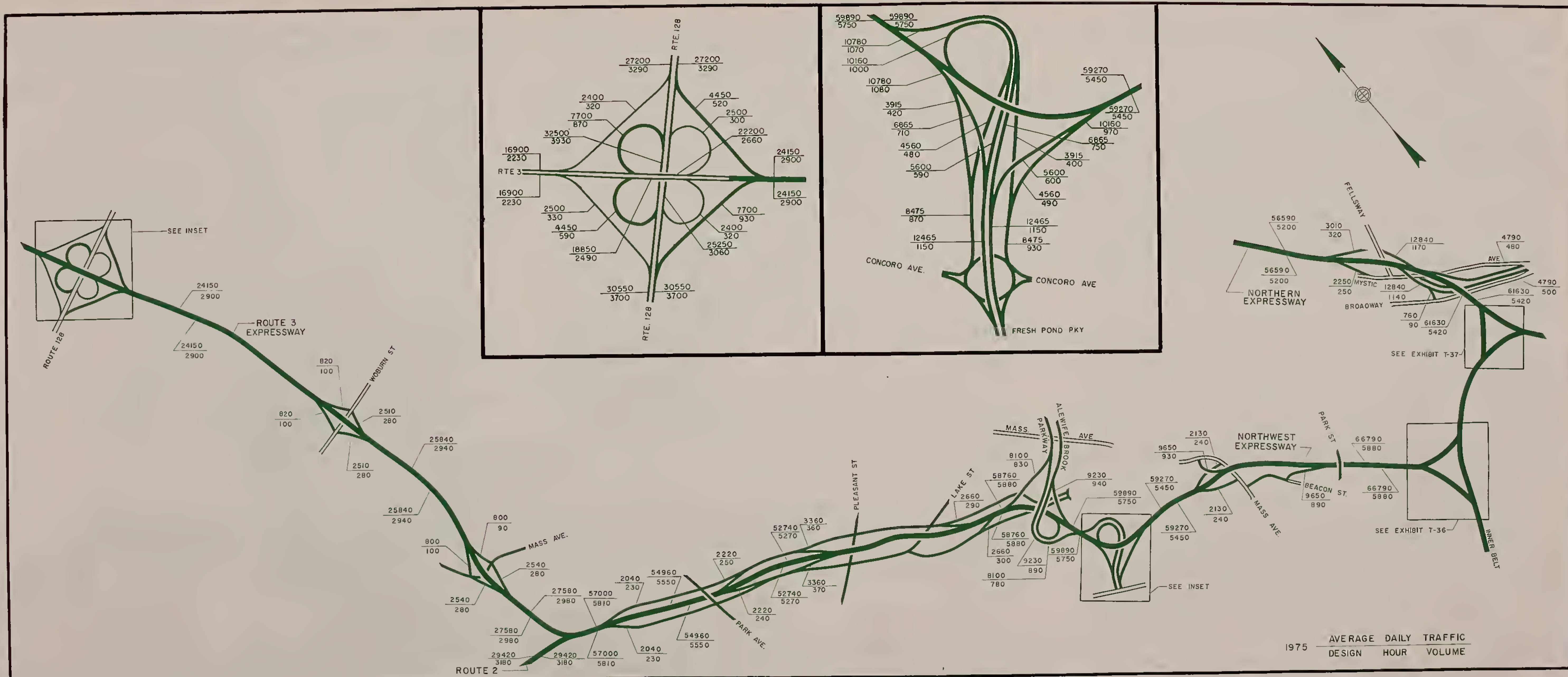


Exhibit T-39

DESIGN ASSIGNMENTS: ROUTE 3, NORTHWEST & NORTHERN EXPRESSWAYS

ALTERNATE LOCATION

Traffic volumes assigned to the Alternate Lacation are essentially similar to those of the Recammended Lacation. Minor variations occur south of the Cummins Highway interchange and these are due to the location of the next sautherly interchange, which provides local service to a slightly different geagraphic area. Fram Cummins Highway northerly to the Inner Belt, the interchange locations and the type of local service are basically the same as shown on the Recommended Lacation.

ROUTE 3 AND NORTHWEST EXPRESSWAYS

RECOMMENDED LOCATION

The Recommended Location of the Route 3 Expressway and the Northwest Expressway are considered for assignment purposes as a single expressway from Route 128 ta the Inner Belt. This expressway interchanges with Raute 128, jains with the prapased Raute 2 Expressway at Appletan Street, Arlington, and interchanges with Alewife Brook and Fresh Pond Parkways, ond with the Inner Belt. The 1975 ADT volumes for this expressway are shown on Exhibit T-39. Design haur valumes are appraximately equal to capacity along the entire sectian from the junctian with the proposed Route 2 Expressway to the Inner Belt. The ADT volumes vary fram 114,000 vehicles after the junction with the

Route 2 Expressway to 133,000 vehicles at the Inner Belt. Four lanes in each direction are recommended for this section of the Route 3 Expressway.

From the Route 128 interchange to the junction with Route 2, the Route 3 Expressway volumes gradually increase from 48,000 to 55,000 vehicles. Two lanes in each direction are recommended for this section. The volumes assigned to the interchange with Route 128 were analyzed and found to require a clover-leaf-type interchange as previously designed. At the two local interchanges between Route 128 and the junction of the Route 2 Expressway, the predominant movement is toward the Inner Belt, accounting for approximately seventy-five percent of all trips assigned to these local access points.

After Route 3 joins with Route 2 at Appleton Street, Arlington, capacity volumes are predicted and local ramp assignments are therefore partially restricted. However, a continuous frontage road system is recommended from the junction of Route 3 and Route 2 to the existing Alewife Brook Parkway, which would serve local needs and provide additional arterial capacity for intermediate-length trips.

A trumpet-type design is recommended at the interchange with the Alewife Brook Parkway. This design would provide adequate traffic service for Alewife Brook Parkway as it now exists. However, if Alewife Brook Parkway is to be reconstructed to expressway standards, a directional-type interchange, as shown in the Basic Design Exhibits for the Alternate Location, should be provided.

The weaving volumes and the limited weaving distance available at the Concord Avenue-Fresh Pond Parkway interchange require that the through movement to Fresh Pond Parkway be separated from the local turning movements to Concord Avenue. The design recommended will adequately satisfy this condition and the local traffic needs.

ALTERNATE LOCATION

The Alternate Location for the Route 3 Expressway is substantially different in concept from the Recommended Location, resulting in wide variances in the volumes assigned. The Alternate Location begins at the present terminus at Route 128 and continues to a junction with the Northwest-Northern Connector. The ADT assignments to this section range from 56,000 vehicles at Route 128 to 77,000 vehicles at the junction with the Connector. Two lanes in each direction, with provisions for widening to three lanes from Route 128 to Ridge Street, Winchester, and three lanes in each direction from Ridge Street to the junction with the Northwest-Northern Connector, are recommended to accommodate the 1975 volumes. As part of this Alternate Location, Alewife Brook and Mystic Valley Parkways must be reconstructed to expressway standards so as to provide a connection between the Northwest Expressway and the Northern Expressway. The ADT volume of traffic assigned to this Connector varies from 66,000 vehicles to 78,000 vehicles, and requires three lanes in each direction.

Directional-type interchanges are recommended at both the interchange of the Connector with Route 3 and with Route 2. The interchange of the Connector with the Northern Expressway, presently under construction, would require the addition of a ramp from the southbound lane of the Northern Expressway to the westbound Connector to accommodate the assigned traffic. However, in recognition of the importance to local traffic desires of ramps under construction, and the great cost of providing the additional ramp, it would not be practical to recommend its inclusion in the basic design.

The traffic assigned to the Alternate Location of the Northwest Expressway, shown on the Basic Design Exhibits, is essentially the same as is shown for the Recommended Location. An eight-lane expressway, from the Inner Belt to the directional interchange with Route 2 and the Alewife Brook Parkway, is recommended.

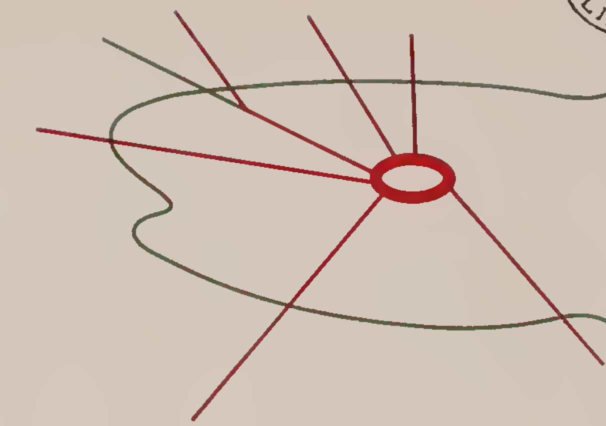
NORTHERN EXPRESSWAY

RECOMMENDED LOCATION

ADT traffic volumes assigned to the Recommended Location in 1975 are shown on Exhibit T-39, and vary from 113,000 vehicles north of The Fellsway interchange to 123,000 vehicles at the Inner Belt. Eight lanes are therefore recommended. Complete local service is provided at The Fellsway interchange. Direct connections to the Sullivan Square viaduct, connecting to Rutherford Avenue, are provided to serve the Charlestown area, and also to relieve the Inner Belt between the Northern Expressway and the Northeast Expressway.

ALTERNATE LOCATION

The Alternate Location provides essentially the same traffic service; however, the local ramps at The Fellsway would not be able to handle the traffic as efficiently as the ramps provided by the Recommended Location. Traffic assignments are slightly higher due to the volume added by the connection of the Route 3 Expressway to the Northern Expressway. The increase to 133,000 vehicles would not change the number of lanes required.



PART IV

SOCIO-ECONOMIC ANALYSIS

SECTION 1 – INTRODUCTION

PURPOSE OF STUDY

Planning a major limited-access expressway system in an urban area is a monumental undertaking. In past years, when highways traversed sparsely populated regions, the effects of the highway upon a community could be readily determined. The complex effects produced by the construction of urban expressways require a prior determination of the immediate and deferred results on both the urban structure and its inhabitants in order that the orderly growth of the community may be stimulated and the social and economic welfare of its citizens promoted. The purpose of this socio-economic analysis is to assess the effects of alternative expressway locations on the communities involved, and to suggest what benefits might accrue following the construction of an expressway system. The expressways included in this Study are located in 13 communities. The Expressway System, however, will affect many of the neighboring cities and towns. An area bordered by future Interstate Route 495, therefore, has been used as the outer limit of the Socio-Economic Study Area. This area includes 121 separate municipalities, as shown in Exhibit S-1, and is referred to in the Socio-Economic Analysis as the Study Area.

As indicated in the *Third Progress Report of the Highway Cost Allocation Study,* ". . . there exists a formidable array of direct and indirect benefits resulting from federal-aid highway improvement in addition to benefits resulting from actual use. Regardless of the label affixed to these kinds of benefits — whether they be identified as an extension of vehicular benefits, transferred benefits, or non-vehicular benefits — what seems significant is that there are real and extensive beneficiary groups other than highway users as such, that reap the advantages of highway improvements and that the total magnitude of these benefits is great."(4)*

The approach devised for this Study included consideration of many elements not treated in detail by past studies. Such

*References will be found in the Appendix.

Exhibit S-1
THE SOCIO-ECONOMIC STUDY AREA

factors as the overall economic base, the shifting population and the movement of people and goods by various modes of transportation, together with the factors of social characteristics, political boundaries and family incomes were all considered in this analysis. As a result of this approach, emphasis was placed on selection of expressway locations that would provide maximum opportunity for the orderly social and economic growth and development of the cities and towns involved. The socio-economic analysis, considered together with the engineering determinations, served as the basis for recommendation of specific locations and their alternates.

METHOD OF ANALYSIS

The effects of the expressways studied were classified in two major groups:

a. The analysis of the physical effects of the expressways as material entities newly introduced into an existing environment.

b. The analysis of the functional effects of the expressways upon the long-range growth and development of the Study Area.

The physical analysis is primarily, but not exclusively, an analysis of the short-run effects upon existing families, local municipal governments, neighborhood groups, local merchants, and the other persons or institutions directly affected by placing an expressway in a particular location. These effects are relatively simple to assess because they relate to tangible alterations in the spatial relationship in and around the expressways. Adjustments in the spatial relationships necessitated by construction, however, will influence the highway's effects in its functional role. The new pattern of land uses and land-use controls will act as limiting factors upon the changes engendered by altered time-distance relationships. The long-term effects of time-distance changes manifest themselves in many functional ways.

The functional or long-range effects of the Inner Belt and Expressway System will result from its ability to fulfill the travel needs of the Study Area in terms of altering the time-distance relationships between homes and offices, factories, shopping facilities, and recreation centers, and between areas of economic activity. Altered time-distances between areas of economic activity and their sources of supply and distribution will create opportunities for the relocation and the new location of economic activity. This new pattern of activity will be reflected in local government revenues and expenditures.

The general principles upon which these analyses were based are those of contemporary systems analysis, in which the chain-like reactions among different sectors of the environment are analyzed to determine the effect of an alteration in one environmental factor upon the other components. The physical and functional effects influence different individuals and groups to varying degrees. For example, a loss of patronage to a merchant in one part of the Study Area will, generally, result in a gain to a merchant in another segment of the Study Area. To facilitate this Study, the affected persons and groups in each separate community were identified and the nature of the effects upon them was carefully determined. Since the individually affected persons and groups are termed herein as "actors," this type of analysis is called an "actor analysis." Actors consist of local governments, residents displaced, community interest groups, commercial and business interests (business and consumer services, retail trade, real estate, and warehousing and truck terminals), manufacturers and public services.

RELATIVE EFFECTS OF THE PHYSICAL AND FUNCTIONAL ANALYSES

The actors remain the same in both the functional and physical analyses, but the actual effects will be quite different. The local governments, for example, experience temporary loss in ratables, yet sufficient businesses and population can be expected to locate in the community following improved highway service to provide the community with compensatory resources. A particular change may have both positive and negative effects, if the actors affected are located in different areas; therefore, equal consideration was given to every actor to make certain that each was assured of maximum future benefits. In the final analysis, it was determined that the potential opportunities for urban growth and development, created in each of the several cities and towns affected by the Expressway System, would more than offset the temporary short-term losses, provided that intelligent, forceful efforts were made to realize the full potential offered by the improved expressway service. The net benefits to the Study Area will be reflected in the greater efficiency of the urban structure as a place to live and work, resulting from the improvements to the area's transportation system.

This Socio-Economic Analysis involves the prior determination of the net benefits for the Study Area. This determination, which includes a forecast of the social and economic conditions to be anticipated in the areas tributary to the Expressway System following construction, is one important consideration in the selection of the Recommended and Alternate Locations from among alternatives.

SECTION 2 – POPULATION AND EMPLOYMENT PROJECTIONS

GENERAL

One of the first problems of assessing the functional effects of the Expressway System was to estimate the probable magnitudes and distributions of the future population and employment that would occur in the Study Area if the expressways are not constructed. This set of projections served as a basis for comparison with estimates based upon construction of the Expressway System. It is recognized that there may be some cross movement in the locations of both people and jobs in the fringes of this area. However, it is expected that these will be proportionately small when compared to the total activity involved.

A thorough study of the basic economic activity in the area, together with projections of future potentials, were made through detailed analysis of the forces that influence employment. Employment trends were analyzed in sufficient separate components to observe the growth, decline, and shifting locations of the more important industries within the Study Area. Employment statistical data was collected and analyzed on the basis of non-manufacturing and manufacturing categories using the Standard Industrial Classifications supplied by the Massachusetts Department of Labor and Industries. The employment estimates provided an important basis for the population projection. When the employment projections were completed, related population estimates were obtained by converting employment into total population. The estimates of population, based on employment, were then checked against simple apportionment and linear extrapolation techniques. Both the population and employment values were then converted into spatial requirements of future developments by assuming an average density of development for each class of activity and for each city and town in the Study Area. The effects of these future developments will be reflected in the individual community's service costs and revenues. Recognition was given to possible future changes in zoning ordinances and subdivision regulations and probable future changes in these were estimated through interviews with officials of the various communities.

METHODOLOGY FOR POPULATION AND EMPLOYMENT PROJECTIONS

Projections of population and employment for 1975 were developed for the Socio-Economic Analysis and to provide basic data for use in the traffic generation and assignment procedures outlined in the Traffic Analysis Section. General population projections for the Study Area were available, but were adjusted as noted herein to conform to the requirements of this analysis. Employment projections for the Study Area were non-existent, and these estimates had to be made independently.

A comprehensive forecast of population and its distribution for Greater Boston, through 1970, was made available by the Greater Boston Economic Study Committee.[8] Two adjustments were made to this information; first, the control total was adjusted so that the new figure would include only those communities in this Study Area; and second, from this new control total, an extrapolation was made from 1970 to 1975, to arrive at the predicted 1975 population control total of 3,600,000 for the Study Area. This population was then redistributed to the communities in the Study Area. Since these distributions did not account for changes in regional transportation, they served as the basis for comparison with distributions based upon construction of the Expressway System.

After the employment projections were completed, an independent population estimate was made by converting the employment estimates into total population. This projection, using the results of both low and high economic estimates, ranges between 3,300,000 and 3,900,000 people. The median of these extremes checks with the population control total of 3,600,000. However, since the individual city and town estimates obtained from the employment predictions take into account not only the extrapolation of existing growth patterns but also the effects of the construction of the Expressway System, they differ considerably from those forecast by the Greater Boston Economic Study Committee.

The employment estimates for 1975 are based on a reconciliation of the results of three separate projections:

a. Apportionment Forecasts.

b. Projection of Local Trends.

c. Production Workers Forecast.

The estimates by apportionment were made by projecting to 1975 the changing proportion of local to national employment, for major non-manufacturing and manufacturing categories, using statistics supplied by the Massachusetts Division of Employment Security and comparable national projections.[6]

Another method of obtaining control totals for employment in the Study Area involved extrapolation of past employment trends of major non-manufacturing and manufacturing categories. The employment statistics reported by the Division of Employment Security represent approximately 80% of the total employment in the Study Area. Government workers, self-employed professionals, entrepreneurs and employees of non-profit institutions are not included in these statistics. With the assistance of the U. S. Department of Labor and the Massachusetts Division of Employment Security, estimates were made of those employees not included, in order to determine the total employment in the Study Area. Past employment in each category was extrapolated to 1975 and the several totals were aggregated to give the second trial employment control total.

Projections of production workers for Standard Industrial Classifications were made on the assumption that the future distributions of production workers would be related to the total industrial employment figures prepared by the Division of Employment Security. For this purpose, the Massachusetts Department of Labor and Industries made available statistics, by town and by manufacturing classification, of the number of production workers, value of stock and equipment, value of output, wages of production workers, and number of establishments. These statistics cover only those firms actually producing within the Commonwealth, and provide a rich source of comparable data on manufacturing activity in Massachusetts. However, since the Department of Labor and Industries collects its data in a manner which is different from that of the Division of Employment Security, these data had to be regrouped according to the Standard Industrial Classification System before they could be collated with data obtained from the Division of Employment Security.

The Massachusetts Division of Employment Security collects its employment statistics on the basis of U. S. Census Standard Industrial Classifications, and reports total employment in manufacturing categories, regardless of whether the actual production is carried on at the particular location, i.e., a regional sales office of a national firm, which manufactures its product elsewhere, would be classified under the appropriate manufacturing category, and the firm's total employment listed. These statistics, therefore, report greater numbers of persons in manufacturing categories than would be anticipated by the ratios of production to total workers, reported in the U. S. Census of Manufacturers.

The data by the Massachusetts Department of Labor and Industries, which incorporates the implicit local rate of technological innovation, was used in the final forecast of production workers, primarily because projections of productivity and value added could be made for employment groups representing the actual manufacturing employment within Massachusetts. In addition, this data would be free of the biases which the estimates by apportionment and by projection of local trends may have inherited from using the statistics supplied by the Division of Employment Security. Furthermore, the projected series could be aggregated into classifications comparable with the estimates by apportionment and projection of local trends.

To make the projections of production workers, the past productivity and value added were put in terms of constant dollars. The productivity and value added were then extrapolated to 1975. From these extrapolations, the number of production workers was computed as the ratio of value added to productivity, and then expanded to total manufacturing employment using ratios of production to total workers, obtained from the U. S. Census of Manufacturers.

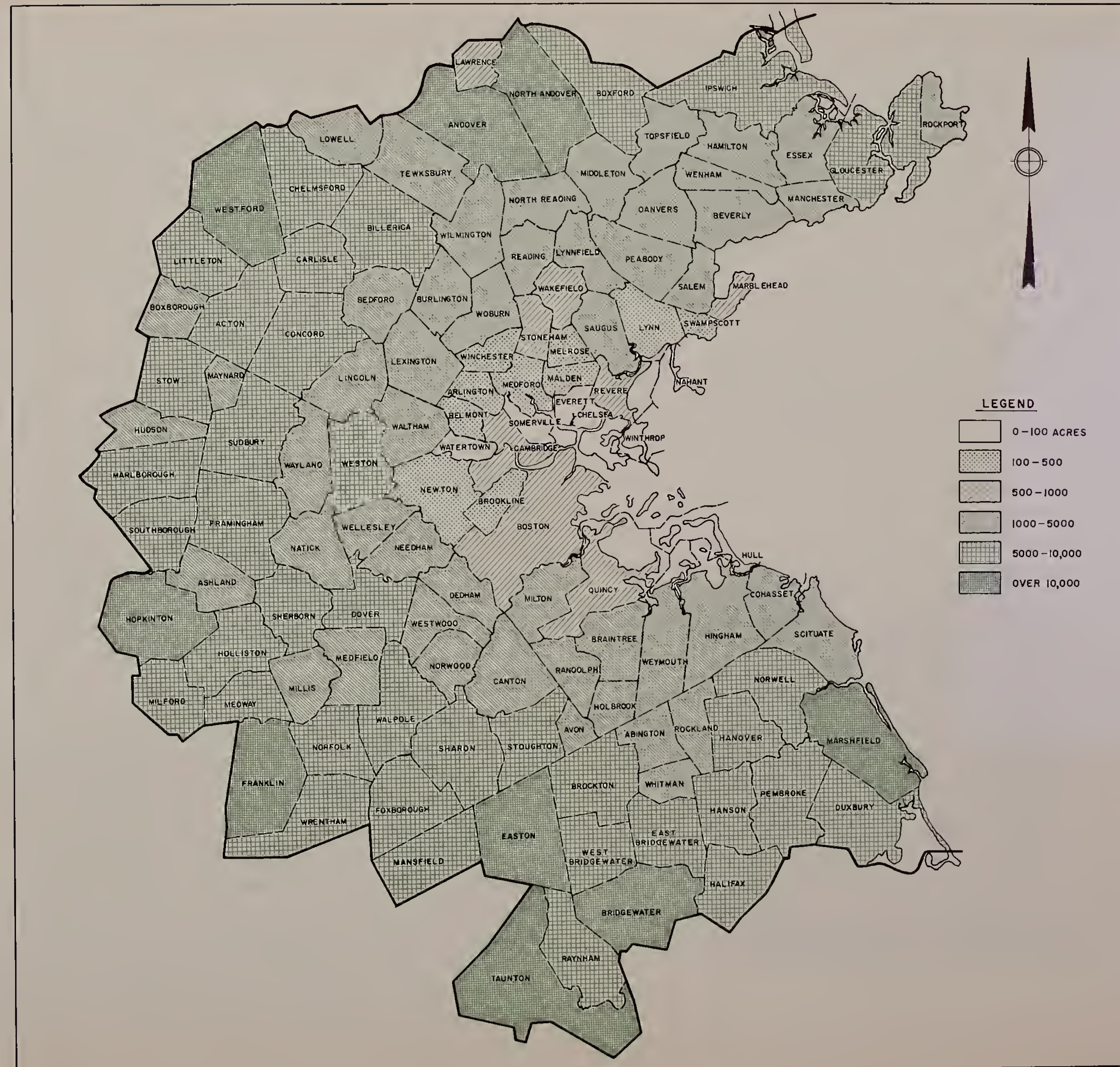


Exhibit S-2

VACANT BUILDABLE LAND ZONED RESIDENTIAL

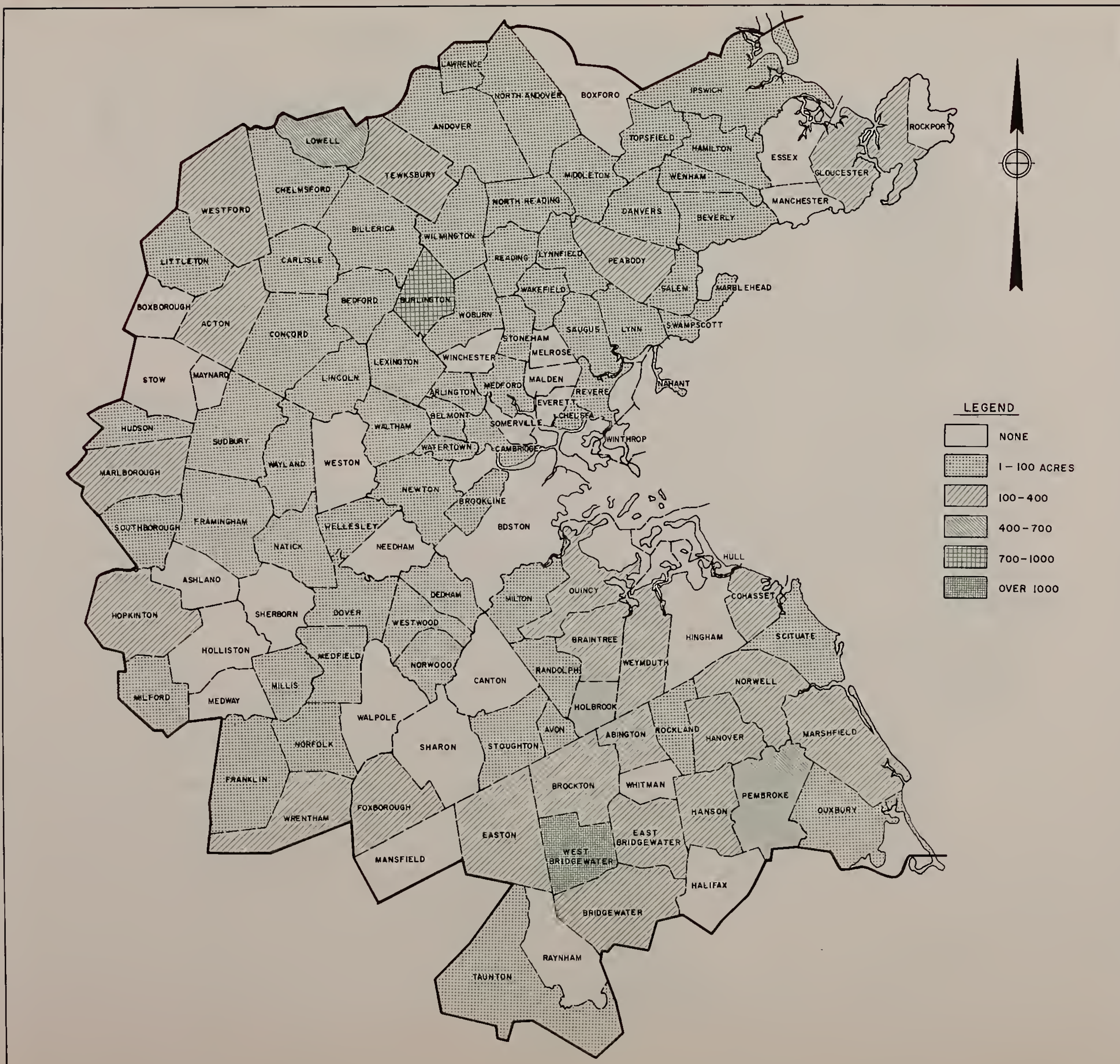


Exhibit S-3

VACANT BUILDABLE LAND ZONED COMMERCIAL

ECONOMIC ASSUMPTIONS FOR EMPLOYMENT PROJECTIONS

Each of the three methods used for forecasting the employment control total for the Study Area involved assumptions and investigations made of the existing distribution and trend of each industry in the Study Area and the national trend of industries. These governing assumptions and investigations concerned national projections, regional assumptions influencing local forecasts, apportionment forecasts, employment extrapolations for major non-manufacturing categories and manufacturing categories, and employment projections and distributions of manufacturing categories.

National projections were made for twenty-six employment categories to permit an apportionment forecast of local economic activity. To measure national activity through 1975, a projection by Dr. Ernst Jurkat[6] was used. The assumptions on which these projections were based were verified by comparison with a series of forecasts made by the National Planning Association.[7]

The regional assumptions influencing local forecasts were formulated after investigation of growth patterns, interviews with public and private agencies, and review of studies on manufacturing trends in the area made by Frank W. Gery[3] and Roger Johnson.[5]

Fundamentally, the apportionment forecast related trends in employment in the region directly to comparable national employment trends. The changing relationship was separately forecast between the number of local jobs available within a particular industry and the number of jobs available on the national scene. With minor modifications, however, the number of jobs available in the local area were assumed to fluctuate directly with national trends.

Extrapolations of local employment were made for non-manufacturing and manufacturing categories, based on past employment statistics furnished by the Massachusetts Division of

Employment Security, analyses of national and local influences, and on special studies for certain key industries, such as the leather, shoe, textile, and electrical machinery (including electronics) industries.

Projections and distributions of major manufacturing activities in the Study Area were made on the basis of data supplied by the Massachusetts Department of Labor and Industries and on the basis of analyses of the past employment and future potential of forty-four manufacturing activities within the Study Area. The trends of these activities were analyzed from this data because it was the only data available which supplied information specifically for regional productivity and output. This comprehensive data was preferred because it contained information on actual manufacturing activities in Massachusetts.

Generally, the inlying areas will benefit from the construction of the Expressway System, particularly in those industries employing large numbers of unskilled and semi-skilled workers which do not have large investments in plant and equipment. Furthermore, because of comprehensive redevelopment programs in the inlying areas, growth will be quite sizable, including the establishment of some large new plants. The outlying areas, particularly at the junctions of the radial expressways with the circumferential expressways, Route 128 and Interstate Route 495, will experience considerable increase in the establishment of new plants relying upon skilled and professional employees, and requiring a considerable investment in plant and equipment.

METHODOLOGY FOR DISTRIBUTION OF PROJECTED POPULATION AND EMPLOYMENT

Two general approaches, the manual distribution approach and the gravity model approach, were employed for the distribution of projected employment and population. The manual distribution approach compares industrial locational needs with the land available for building throughout the Study Area. The gravity

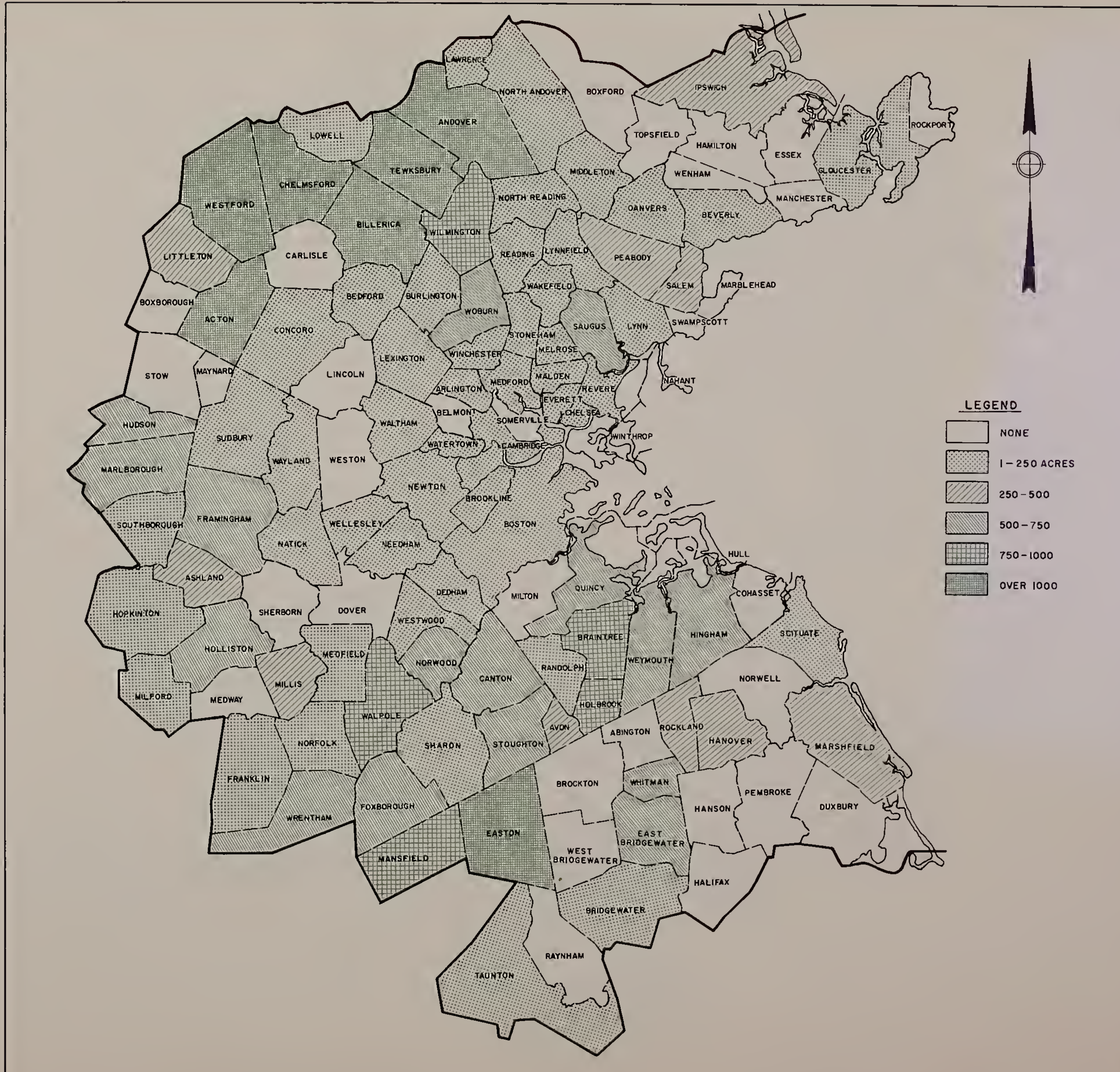
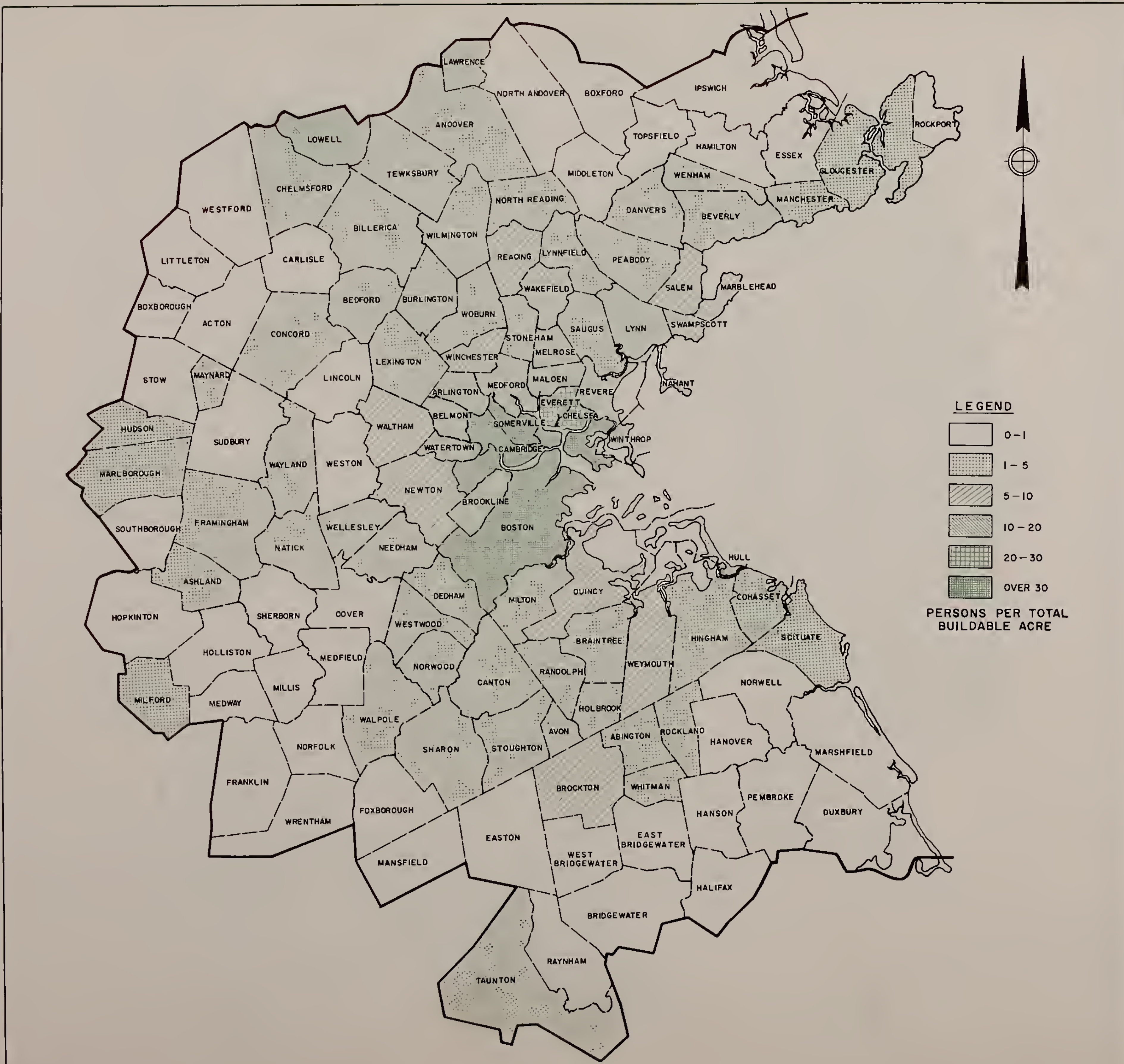


Exhibit S-4
VACANT BUILDABLE LAND ZONED INDUSTRIAL



model approach assumes that the future location of population and employment will alter with changes in the time-distance relationships between population centers within the Metropolitan Area. For example, as its time-distance from the core area changes in the future, a community will assume characteristics similar to those cities or towns along the same sector presently having that time-distance. The results of each method were compared and reconciled to provide estimates for each of the 121 cities and towns in the area and then aggregated and checked against the control totals developed for the Study Area.

The basic data collected for the distribution process included complete itemized land-use data, differentiated by type, by zoning classification, and by the development potential of vacant land. For the inlying densely settled cities and towns, a study was made of urban renewal projects and the probable future re-use of land scheduled for clearance. Several factors investigated were considered to influence the distribution of future population and employment: the land-use patterns and plans of each community, the zoning of available land suitable for building as shown on Exhibits S-2, S-3, and S-4, local utility coverage, local tax rate and assessment policies, the skills of local residents, the proximity to and quality of local modes of transportation, trends in new plant construction, locational needs of different industries, sites currently offered for sale by industrial realtors, trends in housing construction, and population density as shown on Exhibit S-5. It was assumed that inundated areas or vacant land with slopes in excess of 25% would not be developed by 1975, and that marshland and land with slopes of 15 to 25 percent would be developed only if the demand is high.

Four separate employment and population distributions were made by both the gravity model and the manual distribution, or distribution-by-inspection, techniques, assuming:

a. No further expressway construction with a medium level of economic activity.

Exhibit S-5

POPULATION DENSITIES

b. Construction of the Expressway System with a low level of economic activity.

c. Construction of the Expressway System with a medium level of economic activity.

d. Construction of the Expressway System with a high level of economic activity.

The distributions which assumed no further expressway construction were simply extrapolations of existing land-use patterns for each community. While this method takes into account the past rate of transportation change, because it does not account for the new rate of change implicit in the construction of the expressways, it serves as a basis for comparison with those estimates based upon completion of this Expressway System.

The manual distribution approach employs the concept of location theory. It requires a detailed knowledge of the locational requirements of each separate industry and a map showing not only the available sites, but also their particular characteristics. Manual distribution estimates of future population and employment were made by plotting employment statistics on maps showing the regional distribution for each of the 56 separate employment categories, and by analyzing the needs and patterns of existing industry in the area as well as the particular environment of each community.

After locating future industrial employment, the distribution of population was accomplished by utilizing "journey-to-work" theory. This theory utilizes the observed time-distance relationship between homes and jobs in terms of the length of time people are willing to travel to their place of work. This information, which varies from city to city, was represented by a map showing travel times surrounding particular industrial concentrations. Then, utilizing the probable incomes of employees within that industrial concentration, future population was distributed among the existing and potential housing within areas having the proper travel-time relationship. When the residential locations of industrial workers

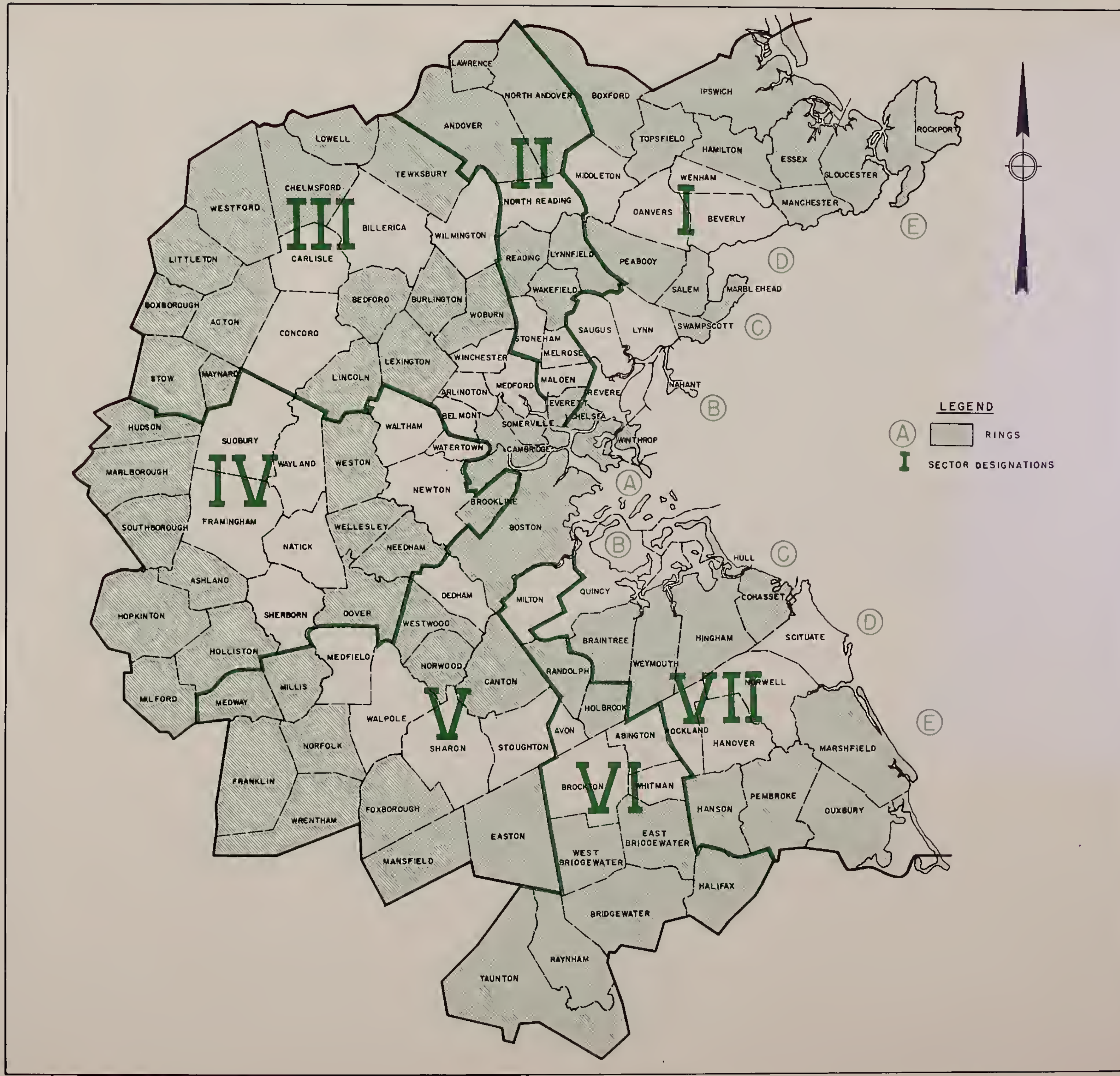
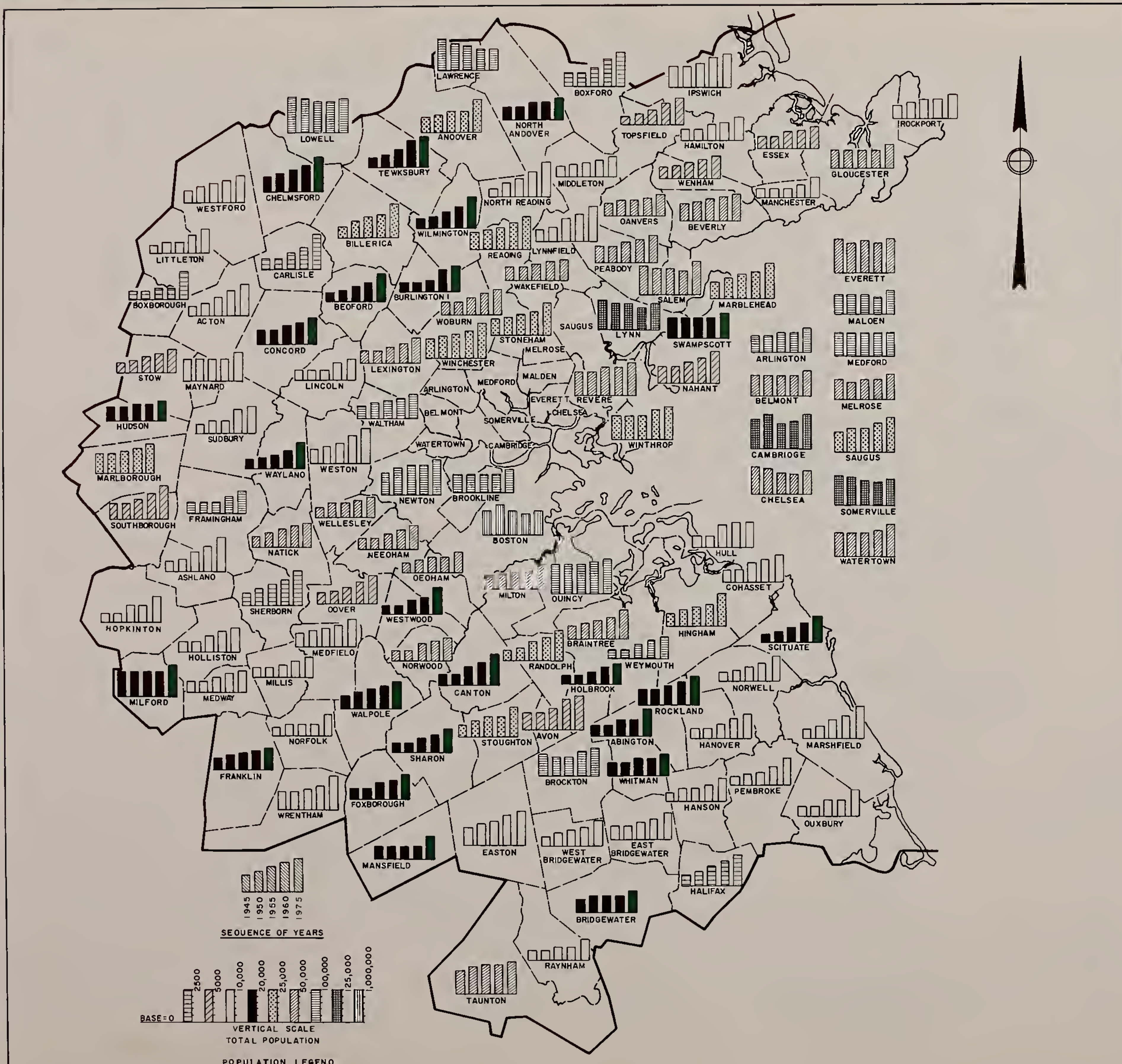


Exhibit S-6

RINGS AND SECTORS OF THE STUDY AREA



were established, residential service activities and their employment were also located. The added employment of these service activities, such as retail trade, service industries, institutions, government and governmental enterprises, also had to be distributed to residential locations on the basis of the "journey-to-work" theory.

The basic assumption of the gravity model technique as used in socio-economic analyses is that the characteristics and degree of development are a function of time-distance between the communities. Time-distance serves as the independent variable upon which the variables of population and employment depend. A gravity model has the advantage of being simple, quick, and objective, but has the disadvantage of placing a heavy reliance upon the single variable of time-distance. Use of time-distance as the independent variable assumes that the other influences on future distributions, such as the willingness of people to travel, the availability of space, and fluctuations in the real estate market, are fixed while in reality they vary independently of time-distance. Therefore, the results of a gravity model analysis must be carefully examined and possibly modified, using carefully weighed judgment.

The basic application of a gravity model to socio-economic distributions is usually suitable only where there is a single political jurisdiction and where the individual cities or towns do not employ defensive zoning restrictions which may hamper the normal pattern of development. Since this Study Area is comprised of 121 independent cities and towns, each having its own zoning regulations which could restrict future development, and the relative size of Boston and its influence over the entire area were not considered predominant, a gravity model technique was employed in this analysis which assumed a restricted future development of vacant buildable land in outlying cities and towns in accordance with existing and proposed zoning regulations. This technique also employed a "Relative Attraction" factor to incorporate the aggregated effects

Exhibit S-7

POPULATION DATA

on each city and town in the Study Area, from both Boston and its regional subcenters. This factor relates the attractiveness of a community for new development to the attractions of surrounding centers, as a function of their respective populations, relative travel times, and relative change in travel times. The relative influences of Boston, Lynn, Lawrence, Lowell, Worcester, Brockton and Providence were considered in this analysis.

In the gravity model technique, the Study Area was divided into rings and sectors which circumscribed and grouped areas having similar characteristics, as shown on Exhibit S-6. Population and employment densities in each of these areas were computed and plotted on distribution curves related to time-distance from downtown Boston. The estimate of the amount of vacant, buildable land to be developed by 1975 was guided by the application of the gravity model together with study, by interviewing local officials and businessmen, of the relative willingness of a community to accept development. The amount of land to be developed was then converted to population, using weighted densities within the zoning provisions, and to employment, using densities of recent development.

The results of this method were contrasted with the other estimates outlined above, to arrive at the best possible comparative estimates. In the reconciliation of the gravity model and the manual distribution estimates, special consideration was given to saturation magnitudes, or maximum potential population, under present zoning regulations. It was considered that the gravity model analysis would provide the skeletal structure of future employment and population distributions, and that careful reconciliation, based upon locational theory, and on examination of past trends would yield reasonable results. The population and employment data for past years and the 1975 projections are shown on Exhibits S-7 and S-8.

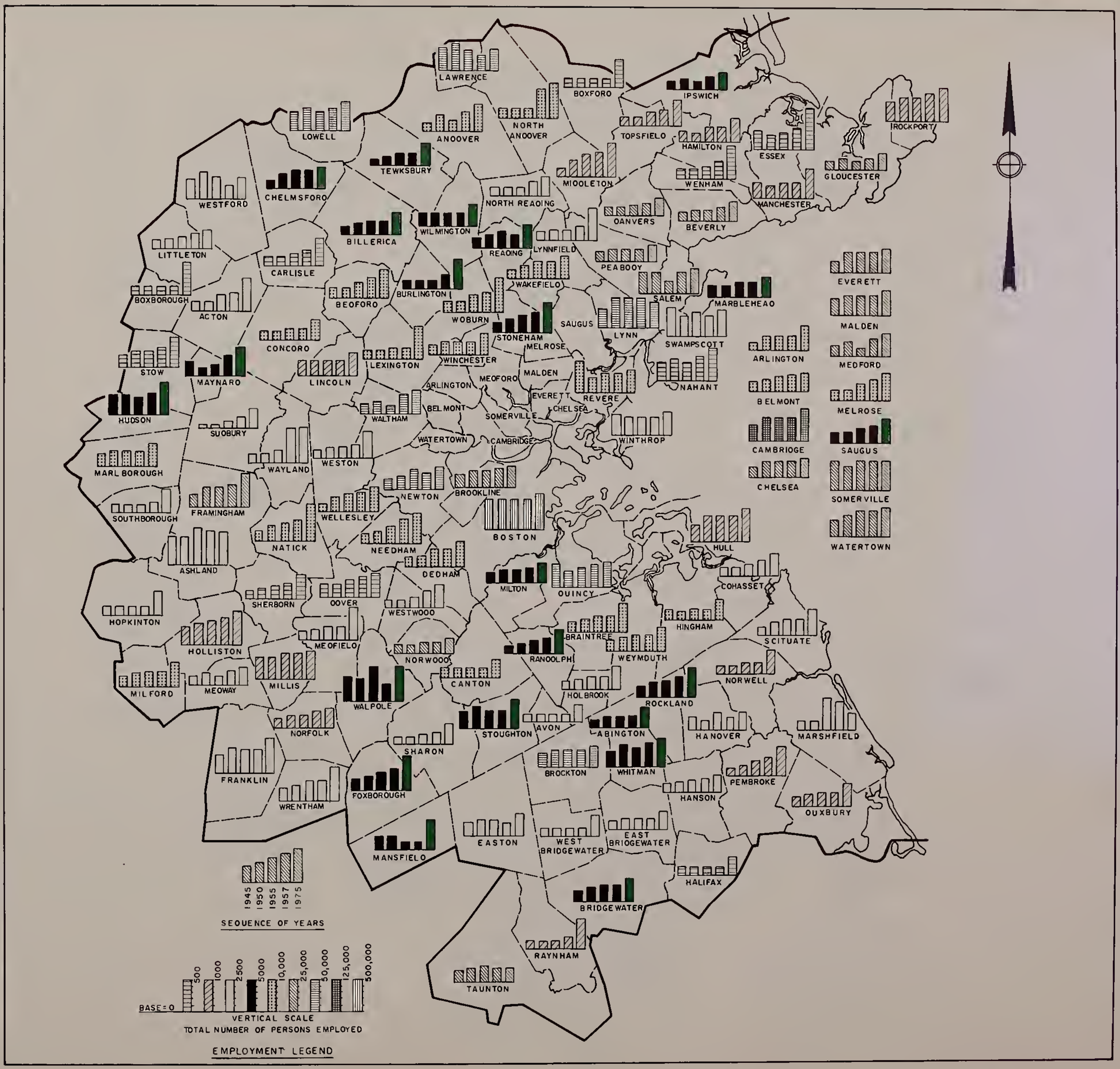


Exhibit S-8
EMPLOYMENT DATA

GENERAL

Expressway construction of the magnitude contemplated in this Study will produce fundamental changes in the structure of the Study Area by altering time-distance relationships among the cities and towns which comprise this area. These alterations will inevitably result in concomitant changes in the locations of future residential and industrial development. The subject of this analysis is the effect the altered patterns in the regional development will have upon the various actors previously identified. A general discussion of the functional effects on these actors is presented here.

LOCAL GOVERNMENT

The altered rate of residential and industrial development experienced by each community will affect the community's future revenues and service costs. If the development rate is reduced, then the community will not only have a lesser growth of tax-producing properties but also lower service costs associated with community development. On the other hand, if the rate of development is increased, the community will obtain increased revenues from taxable properties and be faced with the additional costs associated with such growth. Although local governments will experience a temporary loss of ratables, increased accessibility provided by construction of the Expressway System will stimulate the development of new industrial and residential activities, thereby actually strengthening the communities' tax bases. Future growth and development in a community, however, is not predicated upon construction of the expressways alone. New transportation facilities offer a potential for improvement that must be integrated with other elements of the communities' future planning in order to obtain the maximum benefits afforded by construction of the Expressway System. Generally, construction of the system will accelerate the industrial and residential development of suburban communities. These communities should plan to direct this additional growth through suitable land use controls, in order to maintain a favorable balance between community service costs and revenues.

The effects of construction of the Expressway System on the more densely settled inlying areas will be quite different because of the limited supply of vacant, buildable land within these communities. The proposed network of expressways will ease local street congestion in these inlying areas, thus speeding the movement of people and goods into and out of the core area. In order for these inlying communities to realize their full potential for future industrial activities, suitably located and competitively priced and designed sites must be provided. Interviews with public officials of these communities indicate that they intend to relate their urban renewal activities closely to the expressway construction, thereby capitalizing on the potential for new development afforded by the Expressway System.

COMMUNITY INTEREST GROUPS

Construction of the Expressway System will broaden the scope of the numerous cultural, educational, religious and recreational activities presently located within the Study Area. New activities may also be located at the focal points of the Expressway System, where they will be directly accessible to all sections of the Study Area. Increased accessibility afforded by construction of the system will encourage increased attendance.

COMMERCE AND BUSINESS

BUSINESS AND CONSUMER SERVICES

Construction of the Expressway System will increase the accessibility of business and consumer services to both the labor pool and the patrons of these establishments. The overall development of industrial and residential activities, in communities where these services are located, will further stimulate the development of other commercial activities surrounding the facilities.

RETAIL TRADE

Accessibility afforded by construction of the Expressway System will expand the influence of the present trade areas thereby enhancing the status of retail trade. Opportunities generated because of expressway construction will stimulate the development of new commercial centers and contribute to modernization of existing facilities.

REAL ESTATE

The effect on real property values of altered time-distance relationships will benefit both the property owners and the realtors managing industrial and residential transactions. In general, real estate values will increase in all areas because of the improved time-distance relationship to the downtown area. Increases will be most notable at the intersections of radial expressways with circumferential expressways such as the Inner Belt, Route 128 and Interstate Route 495. It is anticipated that the increase in property values will follow the observed pattern reported in other economic analyses.[4] These analyses indicate that there will be a significant increase in real estate values adjacent to the Expressway System during the years after its construction, followed by a gradual stabilization as the pattern of traffic movement becomes established.

WAREHOUSING AND TRUCKING ACTIVITIES

Generally, the location of warehouses and truck terminals will depend upon the future distribution of manufacturing activities which, in turn, are dependent upon the improved time-distance relationship among the communities in the Study Area following completion of the Expressway System. If the locations of manufacturing activities are radically altered, the distribution of warehousing and trucking activities will be adjusted so they may continue to serve economically their major functions.

MANUFACTURING ACTIVITIES

The alteration of transportation patterns will significantly affect those industries where transportation costs constitute a major portion of their operating costs. If transportation improvements will enable these industries to reduce their operating costs, then they may locate in order to realize these savings. Another factor that will affect the location of manufacturing activities is the future distribution of the labor pool. If certain components of the labor pool are located in a particular area because of increased accessibility afforded by construction of the Expressway System, industries dependent upon this labor may also locate to take advantage of the labor pool. In either case, their total costs will be lowered considerably owing to increased accessibility, thereby per-

mitting them to compete more effectively in the regional and national markets. Their successful participation in these markets will enhance the economic strength of the region.

PUBLIC SERVICES

The future dispersion of population and economic activity throughout the Study Area, and the development of municipalities at low population densities, together with an increasingly higher standard of living, will create new demands for improved educational facilities, public health and medical services, police and fire protection and other public service facilities. Modern transportation facilities will increase the scope and area of influence of these services and permit further improvements, efficiencies and enlarged service areas. Since many of these services regularly rely on motor-vehicle transportation for effective operation, construction of the Expressway System will have a beneficial effect on the many public services which are vital to modern living.

SECTION 4 – ACTOR ANALYSIS OF THE PHYSICAL EFFECTS

GENERAL

The research method for the actor analysis of the physical effects required campilation of basic infarmation to verify the effects of expressway construction upon the various actors previously identified. Comprehensive surveys were undertaken in order to obtain the background data necessary for determining these effects. Interviews were conducted with city and town officials for each of the 121 communities in the Study Area. Information was obtained an population and demography, town finances, subdivision and zoning regulations, utility coverage, rail and bus transportation service, major employment centers, tax-exempt parcels, and future plans for urban renewal and new development. With the cooperation of the Greater Boston Economic Study Committee, land-use and zoning studies were undertaken throughout the Study Area, except for a few inlying cities and towns where this information was readily available. Detailed field surveys were undertaken along the expressway corridor locations to obtain information far each individual parcel, pertaining to its use, the age and condition of the structure, number of dwelling units, number of off-street parking spaces, and the name, location and type of non-residential activity.

To supplement the above, a series of additianal interviews were undertaken with realtars and leaders of community interest groups within the corridors of the expressway locations. From these interviews, information was obtained on future plans for expansion and development, the manner in which public and private facilities would be affected, actual prices of recent praperty sales, and the income and rent characteristics of households in the corridors of expressway lacation.

A detailed survey of property values was undertaken by analysis of recent real estate transactions [1], which permitted estimates to be made of the ratios af assessments to fair market values within the various expressway corridor locations. This infarmatian served ta permit an understanding of the kinds of properties lacated in these corridors and ta provide a basis for preparing the right-af-way cost estimates.

A general discussion of the physical effects on the various actars is presented here.

LOCAL GOVERNMENT

The local governments will benefit from slum clearance by candemnation of blighted areas for expressway rights-of-way; thus construction of the Expressway System can implement plans for renewal and redevelopment. In many instances, the division af land uses is facilitated when the expressway lacation separates industrial areas from declining but salvageable residential communities.

The acquisition of taxable properties for construction of the system will cause some temporary loss in revenue to the local government. However, new commercial and industrial developments locating in the area due to the proximity of the Expressway System will strengthen the communities' tax bases.

RESIDENTS DISPLACED

Residents af property acquired for construction of the Expressway System will incur moving costs, and unless located in a renewal area, which would make them eligible for relocation assistance, low-income families may experience some hardship. A program coordinated with urban renewal activities, involving jaint agency assistance for aid in relocation of those displaced by expressway or urban renewal construction, should be cansidered. This program, together with coordinated construction scheduling, would permit adequate facilities to be made available under renewal construction programming in anticipation af displacements that will be necessary for expressway construction.

COMMUNITY INTEREST GROUPS

Community interest groups will be affected by the future distribution of papulation and employment. Some social clubs, churches, and other non-profit institutions may experience a decline in membership while other new organizatians will be established in rapidly developing communities.

COMMERCE AND BUSINESS

BUSINESS AND CONSUMER SERVICES

Construction of the Expressway System will generally cause the demand for business and consumer services to increase. Those affected by construction af the system may experience temparary short-term effects that will be more than caunterbalanced by renewed activities undertaken in response to increased demand. The presence of the expressways will generally increase the values of these activities, because of an expanded area af influence created by increased accessibility.

RETAIL TRADE

The major effect of construction af the Expressway System upon retail trade will be a modification af the trade areas surrounding the sales outlets. Usually the lass in trade area for one retailer will mean a gain in trade area far another. Retailers will benefit from the proximity of the Expressway System to their establishments through sight-advertising advantages similar to those presently provided along Route 128.

REAL ESTATE

The effect of the Expressway System will be favarable for commercial or industrial real estate as well as for residential property. Recent analyses conducted after completian af various expressways indicate that neighboring residents generally regard highways as conveniences.[4]

On Route 128, more than $175,000,000 warth of buildings employing over 28,000 workers have been built; in June, 1955, there were 39 companies in operation and 14 additianal under construction.[2] Since 1955, many af these plants have been completed and still many more are now under construction.

WAREHOUSING, TRUCK TERMINALS AND MANUFACTURERS

The general effect upon these activities includes increased accessibility to both the labor paal and consumers, sight-advertising advantages, and potential for physical expansion as listed above far the other commerce and business activities.

PUBLIC SERVICES

Various public services may experience the effect af having to relocate some existing facilities as a result of canstruction af the Expressway System.

SECTION 5 – ACTOR ANALYSIS BY COMMUNITY

INTRODUCTION

All communities in the Study Area will benefit to varying degrees as a result of the construction of the Inner Belt and Expressway System. Construction of the System will change the form of this Area. New land-use controls should be adopted by local governments to obtain maximum advantage from the changes engendered by the altered time-distance relationships effected for the 121 cities and towns. Redevelopment plans of local communities, together with plans for private developments, will inevitably be changed to be compatible with and to take advantage of expressway construction. These new programs will have a significant effect on future economic activity in all the communities.

Analysis of the functional effects provided an understanding of the magnitude of long-range opportunities for growth and development which could be realized if local programs are coordinated with expressway construction. The functional effects must be considered in establishing a priority schedule for the expressway construction. The functional analysis was used to predict the probable future effects of expressways on the distributions of population and employment.

These forecasts of population and employment in the year 1975, both with and without the Expressway System, are based on the reconciliation of data for which a wide range of interpretation is practicable. A small modification in the assumptions will inevitably lead to significant variations in the forecasts. The quantitative forecasts, therefore, while useful, are intended to indicate pronounced relative trends and it is these relative trends which are of primary importance.

To relate construction programming to population and employment distribution involves a process of successive approximations. A construction program is first assumed from traffic patterns based on population and employment distributions, assuming all expressways will be built concurrently. The resulting traffic movements implicit in the assumed program will, in turn, affect the distributions and may suggest changes in the initial priorities assigned. This reciprocal process may be continued until the recommended priorities develop optimum practicable loadings on all portions of the Expressway System.

In order to determine the effect of construction priorities on the distributions of population and employment for this Study, a correlation was made between past highway construction and community growth. This correlation showed that there is a time lag ranging from four to eight years after the completion of highway improvements before the area development rate returns to normal and the full net effects precipitated by highway construction can be assessed. Since the construction period for all expressways included in this Study is within this time range, additional population and employment distributions were not considered to have a significant effect on assignment of construction priorities.

The studies estimated the changed locations of future residential and industrial development within the entire 121 cities and towns and the effects of these changes were analyzed in terms of the various actors for the 13 cities and towns through which the expressways will pass. A summary of this analysis for each is presented here.

ARLINGTON

The present population and employment in Arlington are approximately 50,000 and 4,700 respectively. The trend in the past decade has been an increasing rate of growth, and this trend is expected to continue. Without expressway construction, Arlington will have a population of 54,600 and employment opportunities for 5,500 in 1975. With the construction of the Expressway System the population will increase to approximately 55,800, and employment opportunities will increase to 6,500. More than 250 additional residential acres will be developed in Arlington by 1975, of which only 50 acres are attributable to expressway construction. The remaining acreage will have been developed regardless of highway construction. The municipal operating costs attributable to this residential development will be partially offset by increased industrial and commercial expansion. Employment gains during this same period will add to the community's revenues. It is expected that, because of expressway construction, employment will be increased by 1,000 jobs, the largest increase occurring in real estate, service-oriented activities and white-collar categories.

The internal structure of Arlington will not be affected by the construction of either the Recommended or Alternate Location of Route 3. The Recommended Location generally parallels the Arlington-Belmont town line while the Alternate Location generally follows the Arlington-Winchester town line. The anticipated population of 55,800 by 1975, will constitute the major share of Arlington's potential growth. Adding to Arlington's future costs will be a possible new school, accelerated street and utility development, provision for off-street parking in Arlington Center, and perhaps some new recreation areas. The most important factors contributing to an increase in future revenue will be modest industrial and commercial growth. There will be no disruption of Arlington's industrial base, because no commerce or industry will be disturbed by either the Recommended or Alternate Locations of the Route 3 Expressway.

In summary, the net effect on Arlington of the construction of the Expressway System will be advantageous. The construction of the Route 3 Expressway and its extension to the Inner Belt will reduce travel time to all areas, thereby creating substantial transportation advantages for Arlington's manufacturers. Growth in population and employment will increase property values throughout the community, particularly in Arlington Center and along the Boston and Maine Railroad. Since both locations of the Expressway System border the Town, they minimize the initial dislocations and will permit continued and orderly development of Arlington.

Exhibit S-9

ARLINGTON LAND USE, 1959

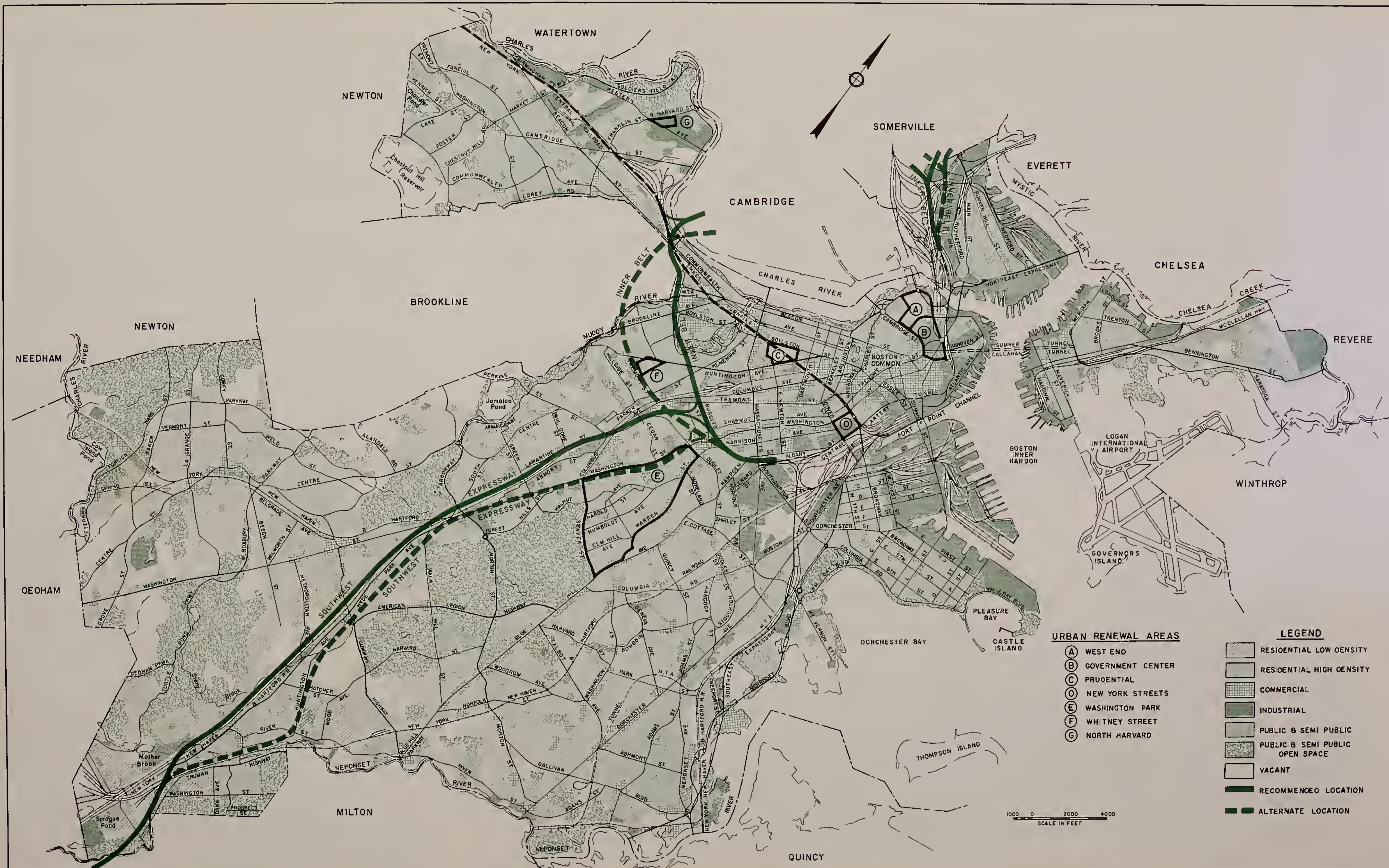


Exhibit S-10
BOSTON LAND USE, 1959

BOSTON

The present population and employment in Boston are approximately 697,200 and 443,600, respectively. The rate of population growth has been declining. However, this trend is being arrested by the local planning activities and new expressways. Without construction of the Expressway System, Boston's population will be approximately 709,000 and employment opportunities 515,000 in 1975. With the construction of the Expressway System the population will increase to 720,000 and employment opportunities to 529,000. These projections indicate that completion of the Expressway System will stimulate both population and employment growth.

The expansion of non-profit facilities will probably be accelerated by the improvement in travel time between the city and the suburbs. An increase in economic activity will result in the need for additional off-street parking areas and local street improvements. The population increase will require the increase of some municipal services. Costs of these services will be balanced, as the increases in community revenue are realized through new commercial and industrial development which will take place in response to an energetic and comprehensive renewal program.

City officials, as well as many private citizens, are presently engaged in a comprehensive program of urban renewal, commercial expansion and industrial development, which will make a significant contribution toward the rebirth of Boston. This is evidenced by the development of the Prudential Center, the Government Center, the West End Development and numerous other commercial, industrial and residential complexes. These developments will in turn encourage voluntary rehabilitation of the surrounding areas. This program is already encouraging the modest return of families from suburban areas.

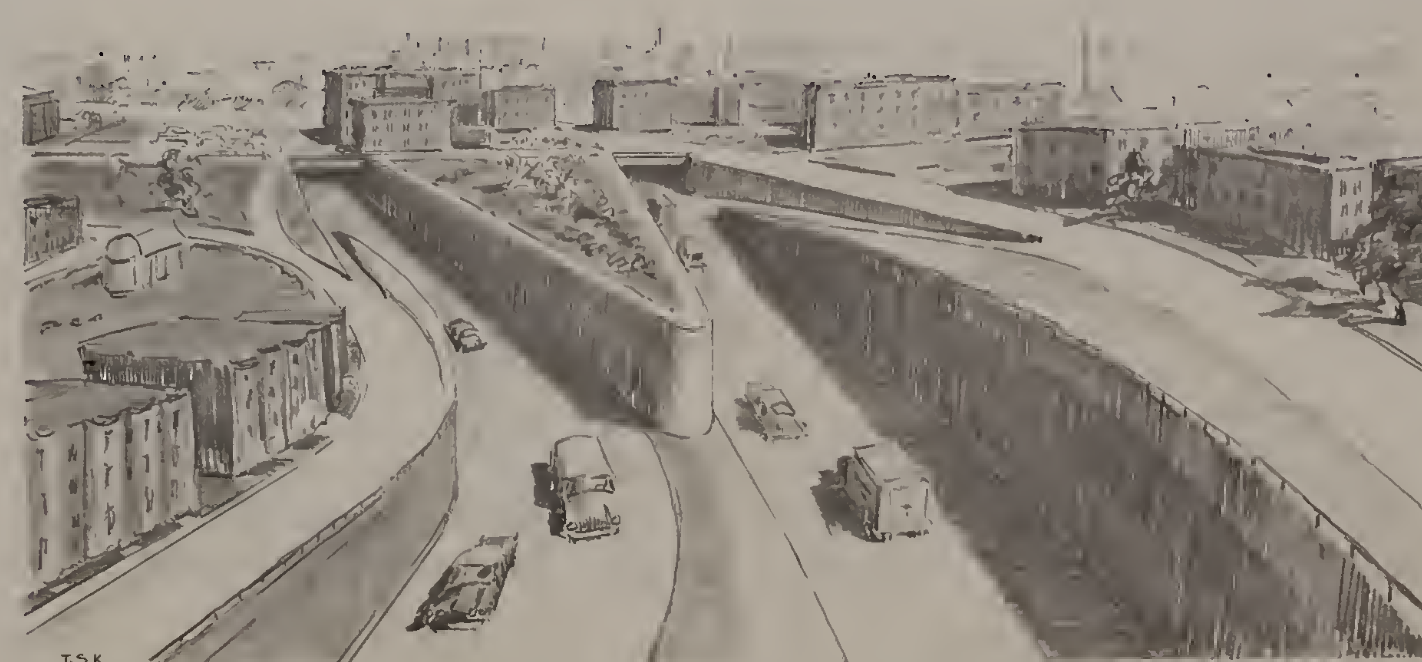
Boston will be affected by the Recommended and Alternate Locations of the Inner Belt, the Southwest Expressway and, to a limited degree, by the Northern Expressway. The impacts attributable to construction will be substantially eased by the opportunities afforded by coordination of expressway construction with urban renewal projects.

The Recommended Location of the Inner Belt generally follows the Ruggles Street corridor. This corridor presents complex problems with respect to the many institutions which border it, notably Northeastern University, The Greek Orthodox Cathedral, Wentworth Institute, St. John of Damascus Church, the Boston Museum of Fine Arts, the Gardner Museum, Simmons College, Emmanuel College and Boston University. Through cooperation with officials of these institutions, their problems have been considered in the development of this Study.

The Alternate Location of the Inner Belt generally follows the Tremont Street corridor, in general conformity with the 1948 Master Plan. As with the Ruggles Street corridor, this location also presents complex problems with respect to the many institutions located along its path, including the Mission Church, Longwood-Harvard Medical complex, and Boston University. The problems of these institutions were also considered in the development of the Alternate Location. The location of the expressway along the Tremont Street corridor bisects the area remaining for the expansion of the Longwood-Harvard Medical complex.

The Recommended Location of the Southwest Expressway generally follows the mainline New York, New Haven and Hartford Railroad, without appreciably affecting the urban structure of the area. The Alternate Location essentially parallels Washington Street and Hyde Park Avenue to Cummins Highway, thence parallels Huntington Avenue, Hyde Park and the Neponset River to Route 128. Among the facilities located in the Southwest Expressway corridor are Arnold Arboretum, Forest Hills Cemetery, New England Hospital and Notre Dame Academy.

In summary, the effects of the construction of the Expressway System on Boston will be highly advantageous. A vigorous program of industrial and commercial redevelopment, coordinated with this system, which will provide maximum access to transportation arteries serving the metropolitan, New England, national and world markets, will enable Boston to compete favorably with the outlying communities. Real estate values will increase and the demand for office space will also increase. Along with expressway construction, the present energetic and comprehensive programs of urban renewal and commercial and industrial development will provide the foundation for a better balance in the future economic structure of Boston.



BELMONT

The present population and employment in Belmont are approximately 28,700 and 4,000, respectively. The presently stabilized population of Belmont is not expected to continue, and a limited rate of growth is anticipated. Without construction of the Expressway System, the population of Belmont in 1975 will be 33,000, and the employment 4,600. With construction of the Expressway System the population growth will be limited to 32,000; however, employment opportunities will increase to 5,400.

The Belmont Hill area, the only sizeable tract available for residential development, offers the greatest potential for accommodating the increase in population. The land in this area is subject to restrictions which require a substantial investment for home construction. Prospective purchasers of modestly priced homes will, therefore, seek locations in the outlying towns because construction of the Expressway System will make these communities more attractive for residential development. More than 200 additional residential acres could be developed by 1975, but construction of the Expressway System will limit this to approximately 160 acres.

The major employment gains are expected in local government and in service-oriented industries. The increase in local employment will stimulate expansion of the retail facilities in Belmont Center and in Waverly and Cushing Squares, and of the establishments contiguous to Route 60 and the Concord Turnpike. The increased demand on these facilities will, in turn, create the need for additional off-street public parking areas. The additional tax revenues realized from home construction in the Belmont Hill area are expected to balance the increased costs of the additional municipal services that will be required.

In summary, the net effects of the construction of the Expressway System are so modest that it is difficult to assign responsibility for them specifically to the construction of the system. A reduced rate of population growth and increased employment will enable Belmont to continue its sound financial position.

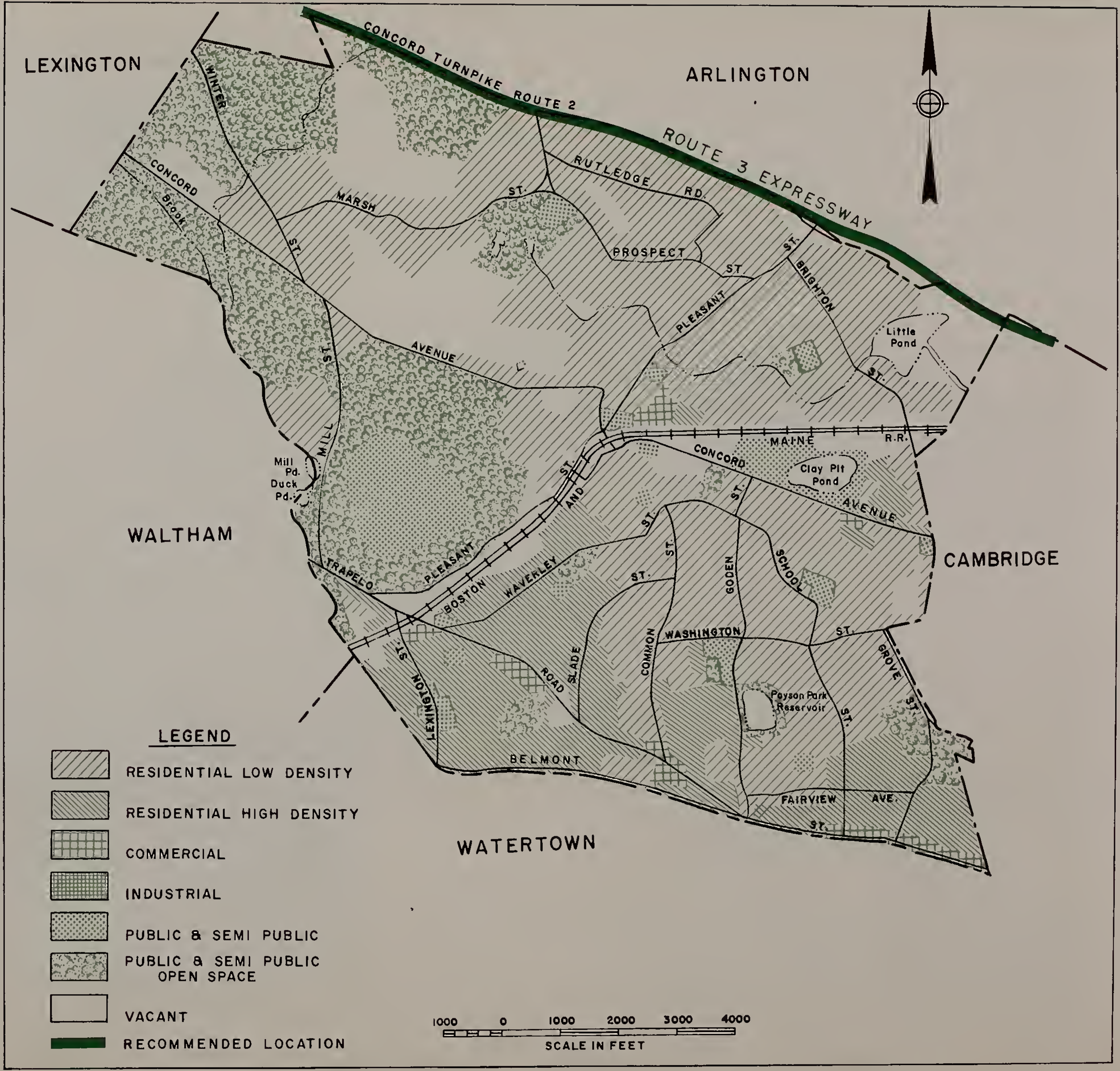


Exhibit S-11
BELMONT LAND USE, 1959

BROOKLINE

The present population and employment in Brookline are approximately 54,000 and 12,000, respectively. The population has been declining over the past decade; however, that trend is not expected to continue. Without construction of the Expressway System, the 1975 population and employment will be approximately 68,800 and 14,700, respectively. With construction of the Expressway System the population growth is expected to be limited to 65,000 but employment will be stimulated to 16,200. Of the expected increase of 1,500 workers, the majority will be employed in service-oriented industries. With few vacant land areas remaining, the population growth, when converted to housing, will take the form of residential conversion and apartment construction, thus increasing residential densities. It is expected that this growth will be comprised of small families which will require minimum municipal services.

The Recommended Location of the Inner Belt Expressway will have little effect on the physical structure of Brookline. The Alternate Location, however, will seriously alter the structure of Brookline by isolating the eastern portion of the town, including the Cottage Farm area.

In summary, the net effects on Brookline of the construction of the Recommended Location of the Inner Belt will be advantageous. Although the rate of community growth will be reduced by expressway construction, Brookline will maintain its solid competitive economic position in the Boston Metropolitan Area. Local retail and service outlets will expand by more than 30 acres to serve the surrounding communities. A reduced rate of population growth and increased employment will provide a better future balance of municipal service costs and revenues. Construction of the Inner Belt in the Recommended Location will prevent further commercial encroachments on the Cottage Farm Area, remove a large portion of the through traffic from local streets in Brookline, and permit the Town to plan effectively for its future expansion.

Exhibit S-12

BROOKLINE LAND USE, 1959

BURLINGTON

The present population and employment in Burlington are approximately 13,000 and 3,300, respectively. Construction of the Expressway System will result in a reduction of the present rate of residential development in Burlington. However, the extension of Route 3 will assure that Burlington will still realize a substantial future growth. Without construction of the Expressway System, the 1975 population and employment will be 15,900 and 4,400, respectively. With construction of the Expressway System the future population will be limited to 14,500 but employment will expand to 4,800.

A reduced population growth rate through 1975 will lower future operating costs, thereby permitting Burlington to stabilize its economy and facilitate orderly completion of its capital improvement program. For example, the reduced rate of population growth will eliminate the necessity for having to provide municipal services for at least 200 residential acres. Employment gains during the same period will add to the community's revenues. While the largest increase in employment will occur in the electrical machinery industry, increases can also be expected in retail employment, research and development industries, and in service-oriented activities. A better economic balance will result from a reduced rate of population growth and its resulting economies, coupled with a rise in property values in the area contiguous to Routes 3 and 128, resulting from new plant and shopping center construction.

In summary, the net effect on Burlington of the construction of the Expressway System will be highly advantageous. The lessening of its growth rate through 1975 will enable Burlington to develop an integrated community that can be adequately served by public and private facilities without major increases in local property taxes.

Exhibit S-13

BURLINGTON LAND USE, 1959

CANTON

The present population and employment in Canton are approximately 12,800 and 3,500, respectively. Without the Expressway System, Canton's 1975 population and employment will be 16,400 and 3,900, respectively. Construction of the Expressway System will stimulate both population and employment growth so as to increase the population to 18,000 and the employment to 5,700 in 1975. By that time approximately 1,000 additional residential acres will be developed, 200 acres of which are attributed to highway construction. Tax revenues from increased industrial and commercial development are expected to balance the increase in the cost of municipal services caused by this residential expansion. Growth is anticipated in local construction and retail activities. Local real estate interests will gain from increased land values, the largest increases occurring in the vicinity of the Route 128 interchange with the Southwest Expressway.

The Recommended and the Alternate Locations cross the Neponset River Reservation in Canton. The only notable physical effect will be a very slight decrease in available open space. In summary, the net effect on Canton of the construction of the Expressway System will be advantageous. The population growth will result in higher residential densities, which in turn may require improved and expanded town services. Without the Expressway System, the balance between net revenues derived from commercial and industrial activities and the net costs of servicing the residential areas would be less favorable for Canton.

Exhibit S-14

CANTON LAND USE, 1959

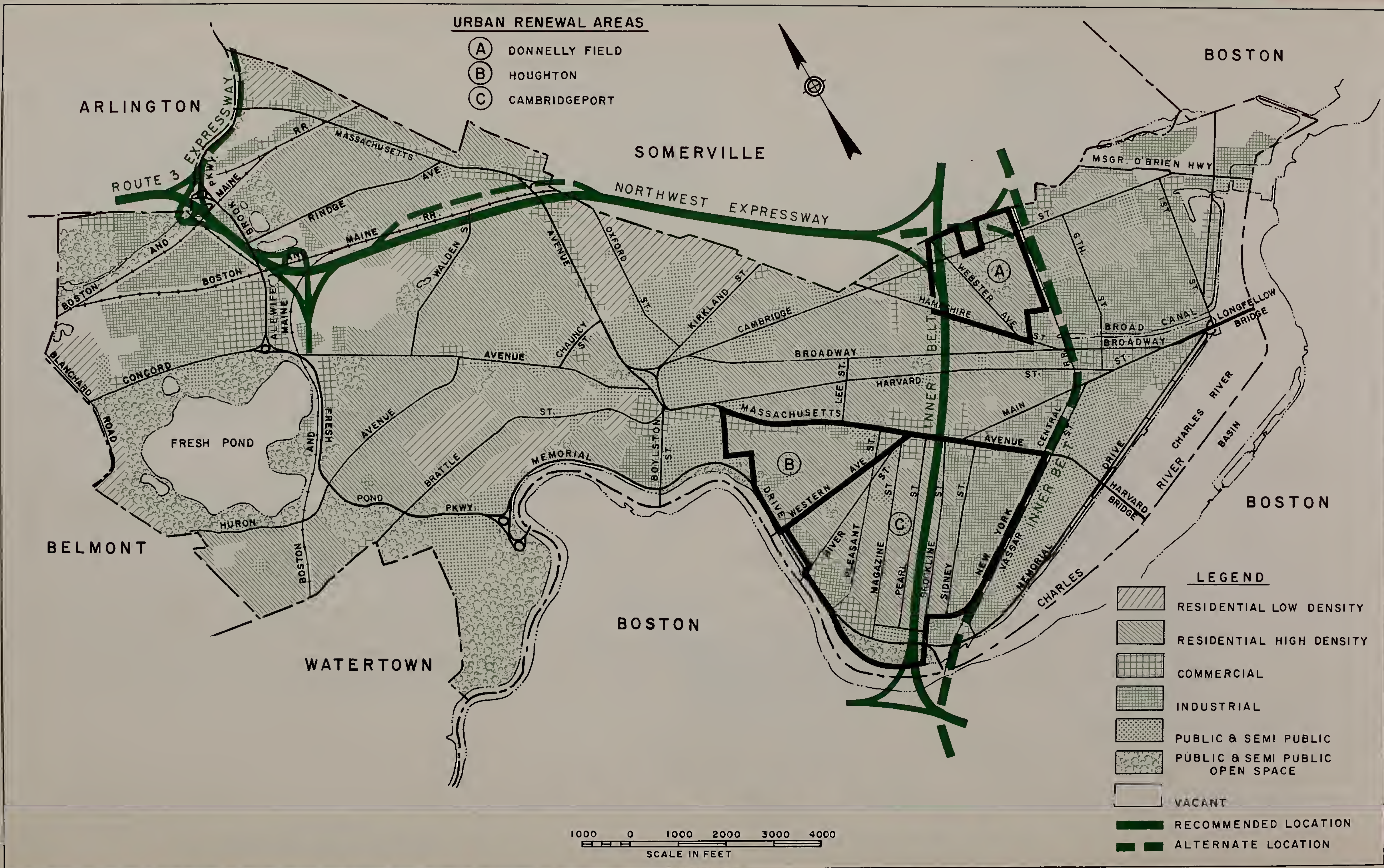


Exhibit S-15
CAMBRIDGE LAND USE, 1959

CAMBRIDGE

The present population and employment in Cambridge are approximately 107,700 and 64,000, respectively. The population growth rate has been decreasing in recent years; however, this trend is not expected to continue. Without construction of the Expressway System the 1975 population and employment will be 114,000 and 87,600, respectively. With construction of the System, the 1975 population and employment will be 116,000 and 115,000, respectively. The net effect of the Inner Belt and Expressway System will be to stimulate the employment growth of Cambridge. The potential increase in population is limited because there are relatively few acres presently available for residential development. The future population densities in the renewal areas are estimated, in this Study, to be the same as at present. Thus the small increase in population growth will take place in the relatively few vacant residential areas, and through the construction of modern apartment buildings throughout the city. The projected large increase in economic activity and employment will result from increased accessibility to the Boston Metropolitan Area via the Inner Belt and Expressway System. The projected increase in population and economic activity will provide Cambridge with a broader tax base. While it is anticipated that the major share of this economic activity will be accommodated in existing and presently planned facilities, it is inevitable that most of the remaining vacant industrial acreage will be utilized. While major employment increases will occur in the research and development industries, increased employment will also occur in service-oriented activities.

Cambridge is affected by the Recommended and Alternate Locations of the Inner Belt, Northwest and Route 3 Expressways. The effects of the Recommended and Alternate Locations of Route 3 will be limited, due to the sparse development along Alewife Brook Parkway and in the vicinity of the interchange between Alewife Brook Parkway and Route 2. The alignment of the Alternate Location follows Alewife Brook; thus it will not disrupt existing neighborhood boundaries or school, fire or police service districts. Both Locations will avoid the majority of the developments along Alewife Brook Parkway. However, remaining vacant land is scarce and the proposed construction may affect the potential expansion of some firms located in the areas involved. The Recommended and Alternate Locations of the Northwest Expressway basically parallel the Boston & Maine Railroad and will have little effect on the urban structure of the community. A number of commercial and industrial establishments, however, will be affected by each alignment. Relocation of these businesses will depend on their current financial stability and the stability of their particular market or field.

The Recommended Location of the Inner Belt generally parallels the Brookline-Elm Street corridor passing through the Cambridgeport and Donnelly Field Renewal Areas. Much of the impact noted in these areas would have occurred under the normal schedule for renewal. Also, a number of commercial and industrial establishments contiguous to Brookline Street would have been affected by urban renewal. The Recommended Location will serve as a physical divider between industrial areas and will also provide access to the industrial area, reducing truck traffic movements through the Cambridgeport area. Increased accessibility to regional highway networks, and active industrial planning by local officials, will probably induce the affected establishments to remain within Cambridge.

The most important effect of the Recommended Location of the Inner Belt to local business is the potential redevelopment of Central Square. An expressway with access to the Square will stimulate a comprehensive commercial development along Massachusetts Avenue. Locally available labor, current renewal activities and accessibility to other sections of the Study Area will provide the necessary attractions to sustain such a development. Improved economic conditions in Central Square will increase the value of commercial and industrial real estate and provide a stimulus for the construction of additional office space. Residential properties in the vicinity of Central Square will be in high demand, and voluntary private rehabilitation will inevitably proceed at a high level.

Further development will result from increased activity in research and development industries. Transportation costs for manufacturing industries in Cambridge will decrease. An increase in manufacturing will result in concurrent favorable development in warehousing and trucking facilities. Cambridge is actively engaged in a program of commercial and industrial development, and the transportation advantages created by the Expressway System are necessary for the successful completion of this program. In this connection, the local government is actively interested in an urban renewal program and has recently filed for approval to expand the Cambridgeport Renewal Area. Realization of these plans will expand the potential economic base of the community.

The Alternate Location of the Inner Belt in Cambridge is a two-level viaduct constructed over the Grand Junction Branch Railroad. Residents displaced in the lower Donnelly Field Area, for the most part, are located within the Donnelly Field Renewal Area and, under the urban renewal program, these families are eligible for relocation assistance. This location disrupts a number of commercial and manufacturing activities located adjacent to the railroad. Although this location cannot provide traffic service comparable to the Recommended Location because it causes traffic to travel longer distances on local streets, it does reduce residential displacements.

In summary, the net effects on Cambridge of the construction of the Expressway System will be advantageous. The short-term physical effects can be lessened through proper use of available means of public and private financing for replacement housing. Cambridge has actively coordinated its renewal plans with the Recommended Location to obtain the best practicable benefit from the expressway construction. Comprehensive local planning, increased commercial and industrial activities, and increased employment will enable Cambridge to expand its economic base and thus provide for a better balance between future revenues and costs.

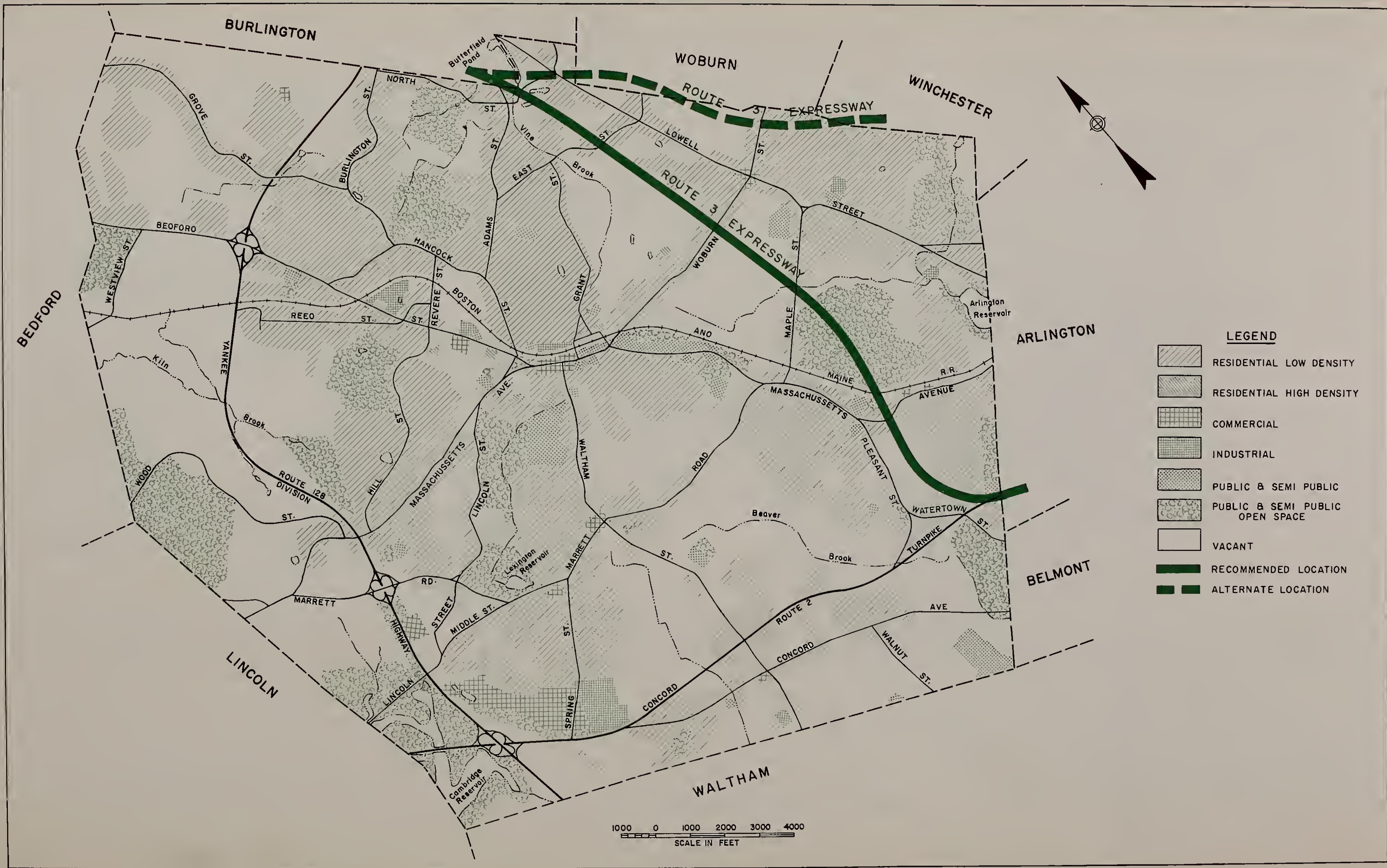


Exhibit S-16

LEXINGTON LAND USE, 1959

LEXINGTON

The present population and employment in Lexington are approximately 27,700 and 3,200, respectively. The population growth hos increased rapidly over the past decade, but construction of the Expressway System is expected to decelerate the present rote of population growth. Without construction of the Expressway System, the 1975 population and employment will be 37,700 ond 4,300, respectively. With construction of the Expressway System the population will be reduced to approximately 34,000, while employment opportunities will increose to 9,700. Therefore, construction of the Expressway System will reduce Lexington's 1975 populotion by 3,700, but will increase employment by 5,400 over what might otherwise be anticipated.

The Recommended ond Alternate Locotions for the Route 3 Expressway will result in substontially different distributions of population and employment. The Recommended Location, which passes northeast of Lexington Center, will result in residential as well os commercial development around the Center ond along the areas adjocent to Route 2. The Alternate Location, which passes through the northern section of Lexington, will sustain and perhaps stimulate the present development trends in that section of the town. The location of the Route 3 Expressway will also determine the area of greatest increase in property value. Construction of the Recommended Location is expected to concentrate the greatest commercial development in and oround Lexington Center while affecting only one industrial establishment. The Alternate Locotion, along the northern border of Lexington, will create opportunities for convenience-shopping centers, particulorly in the northeast corner of the town. Since a substantial portion of the anticipated increases in employment are expected in white-collar categories, construction of either the Recommended or Alternate Location will create a desire for office space in and around Lexington Center. Property values in the vicinity of Route 128 at the intersection of Route 3 will further increase when the extension of the Route 3 Expressway is completed.

The Recommended Location has the greatest potential for reducing traffic congestion in Lexington Center. Furthermore, since it passes through a relatively undeveloped corridor, there will be no appreciable effect on existing police, fire and school service districts. Lexington has plans to develop a major street, Emerson Road, in approximately the same location as recommended for Route 3. Integration of these plans with the plans for the Recommended Location of Route 3 will provide substantial savings to the Town, both in direct construction and future street maintenance costs. These savings can be reolized without sacrificing traffic service or creating a physical barrier between sections of the Town. Bridges on the Recommended Location at Adams Street, East Street, Woburn Street, Maple Street and at Massachusetts Avenue will maintoin present local traffic circulation patterns. Interchanges at Woburn Street and Massachusetts Avenue will provide the center of Lexington and the residential areas with convenient and desirable occess to the Expressway System.

In summary, the net effect on Lexington of the construction of the Expressway System is advantageous. The reduction in population growth rate will correspondingly reduce future requirements for municipal services and projected employment will increase. The benefits of the expansion of commercial and manufacturing activities by more than 150 odditional acres will result in an improved future financial status for the town.

MEDFORD

The present population and employment in Medford are approximately 65,000 and 10,000, respectively. The population has declined over the past decade, but it is anticipated that benefits resulting from the construction of the Expressway System, together with active local planning, will arrest the present trend. Without construction of the Expressway System, Medford could anticipate a 1975 population approximately the same as at present, but an increase in employment opportunities to 13,600. With construction of the Expressway System the population will increase slightly to about 68,500; however, it will appreciably increase employment by providing opportunities for 1,600 additional, or a total of 15,200. The expressway construction will increase the amount of land utilized for industrial and commercial activities, thus resulting in the above-mentioned increased employment. These increases are expected to provide a favorable balance between revenue from industrial expansion and added costs due to residential development.

The Recommended Location for the Route 3 Expressway will not enter Medford. The Alternate Locations for the Route 3 Expressway along the Mystic River Valley will not affect the physical structure of Medford, except that substitute recreational facilities will have to be provided for its southern residential section. This problem requires consideration because Medford was previously deprived of other recreational facilities in the construction of the Northern Expressway. The Metropolitan District Commission presently has under study plans to develop a fresh-water basin in the Mystic River estuary for flood control and recreational purposes, similar to that on the Charles River. The successful completion of this project will eliminate the present tidal fluctuations in the estuary, thereby enhancing the value of the surrounding residential and commercial properties. The increased attractiveness of the area will provide the stimulus for residential, commercial and recreational developments in the area surrounding this basin.

Exhibit S-17

MEDFORD LAND USE, 1959

In summary, the net effect on Medford of the construction of the Expressway System will be advantageous. Channeling of through-traffic onto the Expressway System will keep local troffic congestion manageoble within the forecast period. Increased employment opportunities and limited population increases will assure a continued favorable financial balance.

MILTON

The present populotion and employment in Milton are approximotely 26,400 ond 2,000, respectively. The population has increased within the past decade; however, construction of the Expresswoy System will reduce the rate of population growth, since other communities will gain greater relative advantages from construction of the System. Without construction of the Expresswoy System, the population and employment in 1975 are estimated to be 36,500 and 2,200, respectively. With construction of the Expresswoy System, Milton's 1975 population ond employment will be 33,000 ond 2,900, respectively. While construction of the System will reduce the rate of population growth, employment during the same period will be stimulated.

More thon 1,000 odditional residential acres could be developed in Milton by 1975; however, construction of the Expresswoy System is expected to limit this to approximately 650 acres, as a result of the relative attroctiveness of other communities. This lessened rate of populotion growth will result in at least 350 residential ocres, with a potential for housing more than 1,000 families, remoining undeveloped with commensurate reduction in future needs for municipal services. Employment gains during the some period will add to the community's revenues. It is expected that expressway construction will increase employment by 700, the largest increases occurring in service-oriented industries ond real estate. The Recommended and Alternate Locotions of the Southwest Expressway are in the Neponset River Reservation in the extreme western corner of Milton, ond will not result in any measurable physical effect upon the town.

Exhibit S-18
MILTON LAND USE, 1959

Exhibit S-19

SOMERVILLE LAND USE, 1959

In summary, the net effect on Milton of the construction of the Expressway System will be advantageous. Milton will benefit from a reduced rate of population growth and increased employment opportunities created by construction of the expressways. The Town is a well-planned community in sound financial condition. Controlled growth and coordinated planning, coupled with a reduced requirement for future municipal services, together with added employment opportunities will readily permit Milton to balance future community revenues and costs.

SOMERVILLE

The present population and employment in Somerville are approximately 94,700 and 20,500, respectively. The rate of population growth has been declining in recent years. However, transportation advantages created by the Expressway System, together with active local planning, will cause this downward trend to level off. Without construction of the Expressway System, the 1975 population and employment will be 99,500 and 24,500, respectively. With construction of the System the 1975 population and employment will be 98,500 and 26,000, respectively.

There are few vacant, buildable areas remaining in Somerville, and the future population, when converted into housing, will take the form of apartment construction and residential conversion. The smaller population growth resulting from expressway construction will mean that the future requirements for municipal services will be correspondingly less. Employment gains during the same period, together with industrial and commercial expansion, will add to the community's revenues. The major employment increases are anticipated in transportation, service-oriented, wholesale-trade and machinery activities.

Somerville is affected by the Recommended and Alternate Locations of the Inner Belt, Northwest and Northern Expressways. The Recommended and Alternate locations of the Northwest Expressway basically parallel the Fitchburg Division of the Boston & Maine Railroad. Either location will leave a small section in the Lincoln Park Area located between the Northwest Expressway and the railroad. The Recommended Location of the Northern Expressway generally parallels Mystic Avenue, running along the edge of the Ten Hills area. The Alternate Location skirts the Ten Hills area and generally parallels Middlesex Avenue. This location bisects the Mystic River Basin and may have a serious effect on the development of this basin as a scenic and recreational area. Plans for a flood-control project for this basin have already been authorized by the Legislature. The Recommended Location of the Inner Belt is basically within the Boston & Maine Railroad yards, and will have little effect upon the existing industrial and residential development of the community. The Alternate Location is basically north of the Boston & Maine Railroad yards, and will have a greater effect on the residential area than will the Recommended Location.

One of the objectives of Somerville, in recent years, has been to attract more industry to the City. Some of the manufacturing activities affected by expressway construction occupy outmoded plants, and may desire to modernize their operations in new plants in other locations. An active program of local commercial and industrial redevelopment planning, and the transportation advantages resulting from the expressway construction, will make it attractive for these and other industries to locate in Somerville. Construction of the Expressway System is not expected to affect appreciably the total retail commerce in Somerville, although some shops and a small shopping center along Mystic Avenue will be affected.

In summary, the net effect on Somerville of the construction of the Expressway System will be advantageous. In order for the City to arrest its decline, an active program in urban redevelopment and renewal must be pursued. The construction of the Expressway System presents an opportunity for the City to undertake such a program effectively and to realize over-all community objectives.

The Expressway System will tend to remove through-traffic movements, particularly trucking, from local streets. This will improve the opportunity for the success of local business and urban renewal programs. The present balance between local government revenues and costs should be substantially the same in 1975, provided revenues added by industrial expansion are utilized for urban renewal. When urban renewal has been effected, local buying power will be considerably increased, thus yielding added revenues to local merchants. Land values will increase in and near the Boston & Maine Railroad yards and in the areas contiguous to the Expressway System. Increased access to a national transportation network will enable Somerville's industries to consolidate their competitive positions.

WINCHESTER

The present population and employment in Winchester are approximately 19,400 and 2,700, respectively. It is anticipated that the present rate of growth will continue. The construction of Routes 128 and 3 in past years stimulated the rapid growth of Burlington and Woburn but did not appreciably affect Winchester. The completion of the Route 3 Expressway will also have little influence on the population growth of Winchester but could produce a measurable increase in employment growth. Without construction of the Expressway System, the 1975 population and employment will be 25,000 and 4,000, respectively. With construction of the expressways the 1975 population will also be 25,000 but employment will increase to 5,400. The employment increase is dependent upon the town taking specific action to attract additional commercial and industrial development by increasing the amount of land zoned to permit these activities. Without this change in zoning, the employment increases may be limited to only 500.

The Recommended Location for Route 3 will not pass through Winchester, and therefore no physical effects will result. The Alternate Location will reduce available recreation areas, since it will pass through the Winchester Country Club and the Mystic Lakes. If the expressway is so located, the town may be able to purchase the remaining holdings of the country club, or other areas may be obtained, to provide facilities for the southwest section of town. Under either arrangement additional capital expenditures will be involved.

In summary, the net effect of the construction of the Expressway System on Winchester will be advantageous. Construction of the Expressway System will reduce the through traffic on Winchester's local street system and increase the employment potential in Winchester, which will enable it to continue its present sound financial position.

Exhibit S-20
WINCHESTER LAND USE, 1959

WOBURN

The present population and employment in Woburn are approximately 31,200 and 6,700, respectively. Residential growth has increased rapidly in the past decade and this high growth rate is expected to continue. Without construction of the Expressway System the 1975 population and employment of Woburn will be 33,600 and 7,800, respectively. With construction of the expressways the 1975 population and employment will be 34,500 and 10,600, respectively.

Approximately 300 additional residential acres can be developed by 1975, of which 75 acres are considered attributable to highway construction. While construction of the Expressway System will stimulate population growth only nominally, it is anticipated that future employment in Woburn will be greatly stimulated. The major employment increases are expected in the electrical machinery and chemical industries and in service-oriented activities, an expansion amounting to more than 360 acres of new development. The construction of the Route 3 Expressway will have little effect on the existing structure of Woburn. The Recommended Location will not pass through Woburn, and the Alternate Location passes through the western corner of the town. No commercial or manufacturing activities will be affected by either location.

In summary, the net effects on Woburn of the construction of the Expressway System will be advantageous. Increased tax revenues from commercial and industrial development will offset the increase in operating cost for added municipal services resulting from the increased population growth. Without construction of the Expressway System, the balance between future community revenues and costs would be less favorable.

Exhibit S-21

WOBURN LAND USE, 1959

SECTION 6 – SUMMARY AND CONCLUSIONS

Continuous and accelerated urban and suburban growth have greatly aggravated existing problems of urban traffic congestion. Recognition of these problems has resulted in a necessary shift in federal and state emphasis from the construction of rural highways to the construction of urban expressways. The Federal Aid Highway Act of 1944, which provides federal assistance to states for the construction of urban highways, is the prime example of such recognition. The consideration of the social and economic effects of expressways upon a community, as a factor in the selection of a specific location, is recognized by both Federal and State Governments.

The purpose of the Socio-Economic Analysis in this Study was to determine the effects which alternative locations of the Inner Belt and Expressway System would have on the various communities in the Economic Study Area. The first step of this analysis was the review of past studies that dealt with the evaluation of socio-economic effects of previous expressway construction. Most of these past studies were analyses of effects after completion of highway construction, and therefore provided guidance for the projection of future highway benefits, and focused attention on the effects and attendant problems that could be anticipated as a result of expressway construction in urban areas.

The Socio-Economic Study Area is comprised of 121 cities and towns which will be serviced by several radial and three circumferential expressways. The analysis of this area includes the concurrent effect of many factors such as:

a) The overall economic base,
b) The shifting of population,
c) Social characteristics,
d) Political boundaries,
e) Family income factors,
f) The ability of the individual municipalities to control land use.

To accomplish this analysis, a gravity model technique was developed that encompassed the specific prevailing conditions. The analysis, though broad and complex, was unified by means of social science theories. The procedures and objectives involved consideration of alternative locations of the Inner Belt and Expressway System which would maximize the system's contribution to the long-range growth and development of the cities and towns within its influence. The study furthermore involved a determination of benefits that would accrue to the individual communities following the construction of the Expressway System.

The results of the Socio-Economic Analysis showed that, in most cases, the functional effects were of minimal influence in the selection of the Recommended Location, because of the proximity of alternative locations within a corridor. However, the results of the analysis of the functional effects indicate that all communities involved will benefit from the expressway system construction. The functional analysis provides understanding of the potential for development which the construction of the expressways can provide for all communities within the Study Area.

Population and employment projections and distributions for the year 1975 were made, both assuming construction of the Expressway System and assuming normal growth without construction of the system. This procedure permitted the analysis of those effects which are directly attributable to construction of the expressways. Only 13 communities will be physically affected by the location of the expressways within their boundaries. The effects on these communities were discussed in Section 5. Essentially concurrent construction of the Expressway System will insure a small differential effect on the competitive positions of the individual cities and towns in the Study Area with relation to each other. Improved travel time between the Core Area and the suburbs will, in many instances, tend to cause residential development to pass over inlying communities having relatively high land costs, and concentrate in the outlying cities and towns. Accordingly, the future distribution of population and employment will be more diffused.

The Core Area will tend to attract, to an even greater degree, those industries dependent upon advantages of consolidation. Communication-oriented industries, and industries dependent upon a relatively unlimited labor pool, will inevitably find core sites more attractive. Transportation-oriented industries, presently located in and around the congested area, will greatly benefit from the improved transportation service provided by expressway construction. It is considered that future suburban business growth will be comprised largely of convenience and standard retail outlets, consumer service facilities, highway transportation-oriented industries which serve regional markets, and local government employment.

If the Expressway System is not constructed, and other transportation improvements are not made to the present network in the Boston Metropolitan Area, it is expected that population and economic activity will tend to concentrate generally in the areas in close proximity to the existing highways and other transportation facilities. The Route 128 communities will, under this condition, continue their rapid growth, while outlying communities, not presently being serviced by expressways, will offer less advantageous transportation facilities, and therefore will experience slower growth. Travel conditions throughout the area will deteriorate, contributing toward an accelerated decline of the Core Area and a retarded growth of the outlying suburban communities. Local development and redevelopment plans cannot, under these conditions, be brought to fruition, and the overall economy will be adversely affected. Increased transportation costs, due to traffic delays, will be reflected in the price of commodities, thus impairing the competitive position of the Boston Metropolitan Area with respect to New England and national markets.

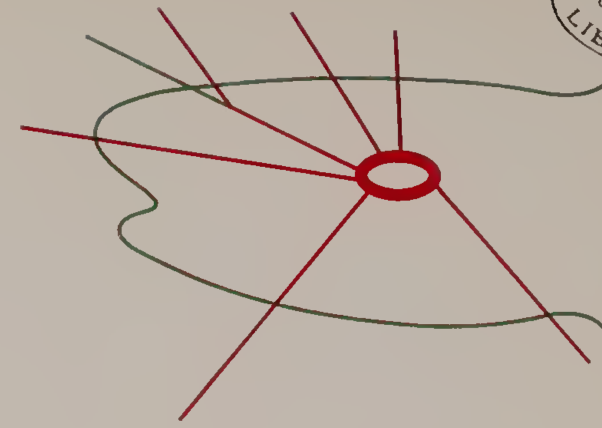
Expressways will be of maximum benefit to a particular community when the community effectively integrates its land-use plans with expressway locations. Therefore, realization of the full potential of the Expressway System is dependent upon the public and private agencies that are responsible for guiding the future development of each community. Expressways will make a significant contribution, but full development of potential resources can only be achieved if expressways are considered as a vital component of the overall transportation system that is required to serve the movement of people and goods. In order to achieve an integrated pattern of transportation services promoting economic growth, expressway construction must be coordinated with plans for port development, airport usage, and the future role of rapid transit and the railroads. In this connection, the movement of persons in dense urban areas must be served by both public and private modes of transportation. It is apparent that the

Expressway System will not by itself solve the problems of transporting persons and goods within the Study Area. Construction of the system will result in a more even distribution of future population throughout the Study Area. It will become increasingly difficult to provide service for these new developments with existing means and routes of transit service. It will be necessary to plan ahead continuously in recognition of future requirements, and to adopt the role and techniques of public transportation to the needs of the public.

The Commonwealth of Massachusetts is currently undertaking a comprehensive program of expressway construction through densely populated urban areas. The successful completion of this program will give a new freedom of movement to the workers, shoppers, business men and residents, and promote the development of the economic potential of the entire Study Area. These benefits can be achieved with minimal difficulty for those who may be physically affected. Where household displacements are necessary, an urban renewal program can help to provide alternative accommodations. Through coordination of effort, the Commonwealth and the communities of the Boston Metropolitan Area can establish a program which, while achieving the long-term functional benefits, can also fully minimize the temporary physical effects, particularly those related to the necessary displacement of householders. This program will provide an opportunity to work together in the construction of the vitally-needed Expressway System.

It is important that a continuing record be kept of the actual economic advance of each community following the completion of the Inner Belt and Expressway System, by determining the extent of development in the several communities. This record would provide an empirical basis for continual refinement of the study methods employed in this analysis so they may be applied to similar socio-economic analyses in the future.

The future form of the Study Area will be a series of residential sectors radiating out from the Core Area, bordered by commercial activities which will develop along the Expressway System. The focal points of these developments will be the areas surrounding the interchanges between the radial and circumferential expressways. Boston will remain the "hub" of the region, and, with the impact of current revitalization, will have a greater economic influence on the growing regional sub-centers.



PART V

EXPRESSWAY SYSTEM

SECTION 1 – THE INNER BELT EXPRESSWAY

INTRODUCTION

The basic functions of the Inner Belt Expressway are to serve as:

a. A collector-distributor of vehicular traffic, to or from the various radial expressways, having origin or destination in the core area of Metropolitan Boston.

b. An inter-connector for the transfer of vehicular traffic between the radial expressways for traffic with origin or destination either in Metropolitan Boston or on any part of the Interstate System.

The diameter and corresponding length of the Inner Belt are predetermined by these basic functions. If the diameter were too large, the general location would be outside the core area of Metropolitan Boston, and hence would not effectively serve the major desire areas as a collector-distributor of traffic, and the bulk of this traffic would have to continue to use the existing street system for access to the core area. If the diameter were too small, it would not be possible to have all the radial expressways connected directly to the Inner Belt and concurrently provide a sufficient number of local access ramps to distribute and collect traffic adequately. Ideally, the Inner Belt should be located as close as possible to the major traffic generators in the core area, and yet be of sufficient length to allow for connections with the radial expressways, as well as to provide for traffic service to and from the local streets.

The location of the Inner Belt is governed by the highly important physical location considerations in the heavily built-up, complex, urban area through which it must pass. The most important physical controls are the two existing ends of the Central Artery and the location of the crossing of the Charles River. The general land-use controls existing along the Charles River, such as Boston University and other substantial real property on the south side, and Massachusetts Institute of Technology, Cambridgeport Urban Renewal Area, Harvard University, Morse School, Cambridge and Mount Auburn Cemeteries, and the United States Arsenal on the north side, limit the crossing of the Charles River to the area in the vicinity of the Boston University Bridge. This narrow range of possible crossings is compatible with a connection of the Inner Belt Expressway to the proposed extension of the Massachusetts Turnpike, and provides the required length of Inner Belt to permit the connection of the several radial expressways and local ramps within the limits of the design criteria.

With the general location of the control point of the Charles River crossing established, a review of previous reports and extensive field reconnaissance were undertaken to determine feasible locations of the Inner Belt which would connect the following two terminal control points shown on Exhibit B-1:

a. Southerly end of the Central Artery at Massachusetts Avenue in Roxbury, Terminal Control Point 1.

b. Northerly end of the Inner Belt extending from the Central Artery in Charlestown, Terminal Control Point 2.

As a result of this review and reconnaissance, it was decided that a solution of the complex problem of determining feasible locations of the Inner Belt could best be obtained by separating the locations studied into three geographical areas as follows:

a. The Charles River crossing, including the interchange with the Massachusetts Turnpike.

b. Boston and Brookline between the southerly Terminal Control Point and the Charles River.

c. Cambridge, Somerville, and Charlestown between the northerly Terminal Control Point and the Charles River.

The three location controls, two of which fixed the end points and one which generally located the crossing of the Charles River, were strong motivation for separating the locations studied into three separate areas. Furthermore, the location of the Inner Belt in Boston and Brookline is independent of the location in Cambridge; however, the specific location of the Charles River crossing and the interchange with the Massachusetts Turnpike are dependent upon the location both in Boston and Cambridge.

LOCATIONS OF THE CHARLES RIVER CROSSING

GENERAL

The Inner Belt crossing of the Charles River is confined to a limited area in the vicinity of the Boston University Bridge, because of the major land-use complexes on both sides of the river and the requirements for the optimum diameter as noted hereinbefore. Within this general area, there are several major considerations which vitally influence the specific location of the Charles River crossing. Major considerations on the south side of the river are:

a. The extension of the Massachusetts Turnpike into Downtown Boston, its interchange in the Allston Yards of the New York Central Railroad, and the inter-connection of the Turnpike and the Inner Belt.

b. Present and proposed buildings of Boston University and the preservation of its campus.

c. The Commonwealth Armory, the Cadillac-Oldsmobile Building, the Boston University School of Fine and Applied Arts and the Cottage Farm section of Brookline.

Major considerations on the north side of the river are:

a. Present land uses along the river.

b. The Urban Renewal Area between the Charles River and Massachusetts Avenue.

Of various possibilities for entry into Cambridge, only two appeared feasible: at Brookline Street for those locations east of Central Square, and at River Street. Any other points of entry of the Inner Belt into Cambridge would seriously disrupt present and proposed development of the area between the Charles River and Massachusetts Avenue, and would require the acquisition of considerable high-value property by comparison. Further study revealed that the River Street location was not feasible, as described later.

The Cadillac-Oldsmobile Building, the Commonwealth Armory, the Boston University School of Fine and Applied Arts and the commercial buildings along Commonwealth Avenue between Amory Street and Pleasant Street seriously restrict crossings of the river to the extent of channelizing the crossing to a few specific narrow corridors. Boston University's existing and proposed buildings preclude a bridge crossing of the Charles River downstream of the Boston University Bridge; however, a tunnel crossing would be possible in this location although it would pass beneath the proposed Boston University Library. The effect on the Cottage Farm area of Brookline would be minimized, provided the Expressway passed along the eastern and northern edge of this residential area.

SUBSURFACE CONDITIONS

All locations crossing the Charles River in the general vicinity of Boston University Bridge involve similar subsurface conditions. The subsoil in the immediate vicinity of the river is almost entirely dense and granular, with irregular and discontinuous strata of coarse sands and gravels interposed between deposits of fine sand. Within the limits of the river channel, the river bottom sediments consist of soft organic silts and sands upwards of 20 feet thick, underlain by the granular materials encountered along the banks. The depth to bedrock is more than 100 feet below channel bottom. Bridge foundations in such soils present no special problems other than requiring adequate precautions against scouring by the river. Excavation in the river for bridge foundations or for a cut-and-cover tunnel section, can best be effected by open excavation inside cofferdams, carried sufficiently deep into the dense granular materials, and sealed by tremie concrete.

MASSACHUSETTS TURNPIKE CONNECTIONS

Throughout this Study the uncertainty of the status of the extension of the Massachusetts Turnpike from Route 128 into the South Station area of Boston imposed the problem of determining an Inner Belt connection that would be compatible with either a toll facility or a free expressway to the west similar to the 1948 Master Highway Plan recommendation. Many possible solutions of an Inner Belt connection to a free western expressway were considered in addition to connections to the Turnpike; these considerations increased the extent and complexity of the studies.

Early in 1962, several conferences were held with representatives of the Massachusetts Turnpike Authority to review alternative locations of an interchange of the Inner Belt and Turnpike. The arrangements between the Turnpike Authority and the New York Central Railroad concerning the joint use of the Allston Railroad Yards precluded a bridge crossing of the Charles River entering Cambridge at River Street. Available space in the Allston Yards would be inadequate to accommodate the minimum railroad facilities, the Inner Belt, the Massachusetts Turnpike Extension and interchange connections to the Inner Belt, and the ramps for connection of the Massachusetts Turnpike to Cambridge Street in Allston. Since the Turnpike will be constructed before the Inner Belt, considerable additional construction costs will result from any alteration of the Turnpike. Possible river crossing locations were therefore restricted to the immediate vicinity of the Boston University Bridge.

DESCRIPTION OF RECOMMENDED AND ALTERNATE LOCATIONS

Thirty alternative locations were developed in plan and profile, of which ten locations warranted further detailed study. This detailed study resulted in the selection of the Recommended Location, Alternate Designs I and II as practicable modifications of the Recommended Location, and an Alternate Location.

The Recommended Location of the Charles River crossing begins on the south side of the River, at Beacon Street and Audubon Circle, as an elevated expressway in continuation of the Recommended Location of the Inner Belt in Boston. This location will curve to the west across a corner of Brookline, with the northbound roadway ascending to a position over the southbound roadway to cross the river upstream of the Boston University Bridge as a double-decked structure, and thence along Brookline Street in Cambridge. This location passes over the intersection of the Boston University Bridge and Commonwealth Avenue adjacent to the Cadillac-Oldsmobile Building. Connections west and south between the Turnpike and the Inner Belt are located over the New York Central Railroad on the Boston side of the river. Connections west and north are provided by a separate double-decked bridge upstream of the Inner Belt crossing.

Alternate Design I involves a tunnel crossing of the river. This location remains depressed after passing under Brookline Avenue in Boston, under the Highland Branch of the MTA, under Beacon Street and Mountfort Street and thence into a tunnel under the river, in a location which passes between the Boston University School of Theology and Student Union Building, now under construction, and beneath the proposed library. After crossing the river and entering Cambridge between 640 Memorial Drive and the Eastern Company building, the Expressway passes under Brookline Street and ascends to grade in a location parallel to Brookline Street. The connections to the Massachusetts Turnpike are depressed, and a considerable length of both the Turnpike and the railroad are also depressed a maximum of 19 feet so that the Inner Belt connections to the south can be located under Commonwealth Avenue.

Alternate Design II is similar to the Recommended Location, except that the interchange is located on the south side of the river in Boston and Brookline instead of over the river.

The Alternate Location of the Inner Belt crossing of the Charles River begins on the south side of the river, south of Commonwealth Avenue, between Amory and Essex Streets, as an elevated expressway and as a continuation of the Alternate Location in Boston and Brookline. This location continues northward, crosses the Charles River as a two-level structure immediately upstream of the Boston University Bridge, and enters Cambridge along the Grand Junction Branch of the New York Central Railroad. Connections west and south between the Turnpike and the Inner Belt cross Amory Street at Egmont Street, and pass between the Massachusetts National Guard maintenance sheds and the Commonwealth Armory as a double-decked structure before entering the Allston Railroad Yards. Connections west and north cross Commonwealth Avenue at Amory Street ond again at St. Paul Street, thence joining with the Inner Belt-Turnpike connection to the south over the Armory Motor Pool as a double-decked structure.

DESCRIPTION AND ANALYSIS OF OTHER LOCATIONS STUDIED

ALTERNATIVE LOCATION A

Alternative Location A represents a group of locations which connect a River Street location in Cambridge to either a Ruggles Street or Tremont Street location in Boston and Brookline. These alternatives were unacceptable due to the loss of commercial property in Brookline, the high cost of construction to cross the Turnpike facilities in the interchange area, and the severe impairment of the Allston Railroad Yards of the New York Central Railroad, as noted earlier in the discussions of the Massachusetts Turnpike Connections.

LEGEND

IDENTIFICATION KEY

1 — CITY HOSPITAL
2 — GREEN SHOE MANUFACTURING COMPANY
3 — ELIOT CEMETERY
4 — DUDLEY STATION (MTA)
5 — MTA STORAGE AND MAINTENANCE FACILITIES
6 — FIRST CHURCH IN ROXBURY
7 — JAMES TIMILTY SCHOOL
8 — MADISON PARK
9 — RUGGLES STREET BAPTIST CHURCH
10 — PUBLIC HOUSING
11 — UNITED DRUG BUILDING (NORTHEASTERN UNIVERSITY)
12 — PUBLIC HOUSING
13 — WENTWORTH INSTITUTE
14 — MUSEUM OF FINE ARTS
15 — MUSEUM OF FINE ARTS SCHOOL AND ST. JOHN OF DAMASCUS CHURCH
16 — GARDNER MUSEUM
17 — BOSTON LATIN SCHOOL
18 — SIMMONS COLLEGE
19 — HARVARD MEDICAL SCHOOL
20 — PETER BENT BRIGHAM HOSPITAL
21 — EMMANUEL COLLEGE
22 — BETH ISRAEL HOSPITAL
23 — SEARS ROEBUCK & COMPANY
24 — LONGWOOD TOWERS
25 — AMORY PLAYGROUND
26 — CADILLAC-OLDSMOBILE BUILDING
27 — COMMONWEALTH ARMORY
28 — BOSTON UNIVERSITY SCHOOL OF FINE AND APPLIED ARTS
29 — PROPOSED LIBRARY, BOSTON UNIVERSITY
30 — 640 MEMORIAL DRIVE
31 — JORDAN MARSH WAREHOUSE
32 — MORSE SCHOOL
33 — STOP & SHOP
34 — B. B. CHEMICAL COMPANY
35 — HOYT FIELD
36 — CAMBRIDGE CENTRAL POST OFFICE
37 — CAMBRIDGE Y.M.C.A.
38 — M.I.T. NUCLEAR REACTOR
39 — M.I.T. MAGNET LABORATORY
40 — METROPOLITAN STORAGE WAREHOUSE
41 — CAMBRIDGE CITY HALL
42 — CAMBRIDGE CITY HALL ANNEX
43 — PUBLIC HOUSING
44 — M.I.T. TECHNOLOGY SQUARE
45 — CAMBRIDGE CITY HOSPITAL
46 — DONNELLY FIELD & DONNELLY SCHOOL
47 — PUBLIC HOUSING
48 — COUNTY COURT BUILDINGS
49 — SOMERVILLE INCINERATOR
50 — GROISSER & SHLAGER IRON WORKS

URBAN RENEWAL AREAS

GENERAL NEIGHBORHOOD RENEWAL PLAN AREAS AND AREAS IN PRELIMINARY PLANNING.

AREAS IN ADVANCE PLANNING.

A — WASHINGTON PARK
B — SOUTH END
C — CHARLESTOWN
D — DONNELLY FIELD
E — HOUGHTON
F — CAMBRIDGEPORT

PROJECTS IN EXECUTION STAGE

G — WHITNEY STREET
H — PRUDENTIAL CENTER
J — NEW YORK STREETS
K — GOVERNMENT CENTER
L — WEST END
M — LINWOOD — JOY
N — NORTH HARVARD

MAJOR BUILDINGS & INSTITUTIONS
SCHOOLS, CHURCHES
PUBLIC RESERVATIONS, PARKS
CEMETERIES, COUNTRY CLUBS
RAILROADS & TRANSIT LINES
CITY OR TOWN BOUNDARY LINES
STATE, U.S., INTERSTATE ROUTES
TERMINAL CONTROL POINTS
EXISTING EXPRESSWAYS
OTHER PROPOSED EXPRESSWAYS
RECOMMENDED LOCATION
ALTERNATE LOCATION
ALTERNATIVE LOCATIONS STUDIED

1000 0 1000 2000 3000 FEET
SCALE
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Exhibit B-1
INNER BELT STUDY LINES

ALTERNATIVE LOCATION B

Alternative Location B represents a group of locations which connect a Ruggles Street location in Boston to a Brookline Street location in Cambridge by a tunnel located upstream of the Boston University Bridge. These alternatives were unacceptable as a result of the greatly increased cost of construction, in excess of $55 million, necessary to provide:

a. the additional length of tunnel and depressed roadway,
b. extensive alterations required for the Turnpike interchange facilities,
c. major revisions to the large existing and proposed subsurface structures of the Metropolitan District Commission's sewerage system in the area.

ALTERNATIVE LOCATION C

Alternative Location C represents a group of locations which involve a location of the interchange between the Turnpike and the Inner Belt on the north side of the river. These alternatives were unacceptable due to their severe effect on Cambridge and their inability to provide an adequate interchange for the Turnpike and Inner Belt.

ALTERNATIVE LOCATION D

Alternative Location D represents a group of locations which place the interchange of the Inner Belt and Turnpike within the Cottage Farm area of Brookline. These alternatives were unacceptable due to the high cost of acquisition of right-of-way, and the impact on the Cottage Farm residential section and the commercial section along Commonwealth Avenue in Brookline.

LOCATIONS IN BOSTON AND BROOKLINE

GENERAL

The area in Boston and Brookline between the terminus of the Central Artery at Massachusetts Avenue and the area available for the Charles River crossing has numerous general land-use and property-valuation controls. These controls include the Harvard Medical School complex, Boston Museum of Fine Arts, Northeastern University, Wentworth Institute, Emmanuel College, Simmons College, Gardner Museum, public housing projects, Kenmore Square business area, the business section around the Dudley MTA Station in Roxbury, Fenway Park, Sears, Roebuck and Company, the Ruggles Street Baptist Church, and the Green Shoe Manufacturing Company. Exhibit B-1 shows the various Inner Belt locations studied in this area and indicates that:

a. A location close to downtown Boston and west of Massachusetts Avenue would pass through Northeastern University's campus and either Kenmore Square or the hotel area east of Kenmore Square. The cost of right-of-way along such a location would be prohibitive.
b. The Inner Belt could not be located between Ruggles Street and Tremont Street without destroying the integrity of the hospital and institutional complex around the Harvard Medical School.
c. The Inner Belt could not be located west of Tremont Street, since Highland Park and Parker Hill create a topographic barrier to such a location. A location west of Parker Hill would place the Inner Belt crossing of Beacon Street close to Coolidge Corner in Brookline, resulting in prohibitive right-of-way costs. In addition, extensive changes to Brookline's street pattern would be required to provide adequate local traffic service.

Thus, it was obvious that only two locations warranted consideration. These are:

a. Along Ruggles Street and The Fenway,
b. Along Tremont Street and Francis Street.

Another factor which greatly influences the location of the Inner Belt in Boston is the location of the interchange with the Southwest Expressway. All locations considered for the Southwest Expressway enter the area of possible location of the Inner Belt either along Washington Street or along the New York, New Haven and Hartford Railroad.

The Ruggles Street location of the Inner Belt passes through the lower Roxbury section of Boston, between Washington Street and Tremont Street at Madison Park. The area surrounding Madison Park contains many multi-family dwellings in very poor condition, and is programmed for urban renewal. Demolition is in progress within this area, since many of the buildings have become a menace to public safety and health due to lack of repair and maintenance. This area is therefore ideally suited for an interchange between the two expressways. It is relatively flat; property values are extremely low; it is a sufficient distance from the Southeast Expressway interchange to provide adequate spacing between major interchanges; and there are several major streets leading into downtown Boston to permit direct access to and from the Southwest Expressway, without requiring travel on the Inner Belt.

The Tremont Street location has none of these advantages. The area available at the general location of the intersection of the two expressways contains a high hill and many important buildings and landmarks. However, while this location is unfavorable from the standpoint of the disruption of land-use patterns and physical impact on the area, it would result in a lower construction cost than that for the interchange in the Ruggles Street location, primarily because in this area the Ruggles Street location is depressed while the Tremont Street location is elevated.

TOPOGRAPHY AND SUBSURFACE CONDITIONS

The topography and geology existing along the locations in Boston and Brookline have important bearing on the comparative advantages of the locations studied. The only topographic feature of serious consequence along the Ruggles Street location is Muddy River, which is relocated where it parallels the depressed expressway. The Tremont Street location is influenced primarily by Highland Park and by Parker Hill, which rises 175 feet above Tremont Street. This location also crosses Muddy River; however, the crossing is at right angles. Parts of both locations on the Boston side of the Charles River generally parallel the rim of the Boston Basin. The Ruggles Street location is just within the Basin and the Tremont Street location passes along the shoulder of the rim. The subsurface profiles of each location are therefore markedly different in character.

Soil conditions for the Ruggles Street location are, in general, typical of the usual Boston Basin soils profile. Beneath a surface layer of shallow and random fill, peat of various depths

generally overlies a deposit of Boston Blue Clay. The upper layer of the clay deposit consists of a crust of stiff desiccated clay, below which the consistency is soft. A layer of glacial till is generally encountered below the clay deposit, and this layer of till overlies the bedrock. The depths to bedrock vary, and in some places are up to 250 feet below the surface. The Ruggles Street location traverses the peat-filled valley of the Muddy River in the vicinity of the Fenway. Much of the land along this location was created by the filling of marsh areas. Northerly of Beacon Street, the soil conditions are generally good, with a relatively thin layer of fill overlying granular materials ranging from fine sand to coarse gravel. These granular soils overlie the bedrock which rises sharply to within 40 feet of the surface under Commonwealth Avenue, thence falling precipitously away to the north. The water table is relatively high along the Ruggles Street location in the area from Columbus Avenue to Beacon Street. Appropriate design and adoption of suitable construction techniques, with particular emphasis on controlled dewatering, will permit use of a depressed roadway.

The Tremont Street location involves frequent rock outcroppings from east of Columbus Avenue to Huntington Avenue and, at both ends of this line, there is a discontinuous sheet of till under a haphazard distribution of surface deposits ranging from peat to dense sand and gravel. Peat deposits are most prominent between Massachusetts Avenue and Washington Street, and in the vicinity of the Muddy River.

DESCRIPTION OF RECOMMENDED AND ALTERNATE LOCATIONS

The Ruggles Street and the Tremont Street locations are described below as the Recommended Location and the Alternate Location, respectively. Numerous alternatives to the basic Ruggles Street location were studied in detail to ascertain the most advantageous design for the Ruggles Street location. The most advantageous alternative locations are presented as Alternate Designs I and II to provide comparisons with the applicable portions of the Recommended Location.

The Recommended Location of the Inner Belt in Boston, referred to as the Ruggles Street Location, is along the east side of Ruggles Street and The Fenway. This location begins at the southerly end of the Central Artery, passes over Massachusetts Avenue, and turns westward to pass under Washington Street at Hunneman Street. The elevated Forest Hills-to-Everett MTA rapid transit line precludes a location of the Inner Belt over Washington Street. The Recommended Location interchanges with the Southwest Expressway at Madison Park and continues as a depressed expressway beneath Tremont Street, Columbus Avenue, and the New York, New Haven & Hartford Railroad, and thence parallel to and along the east side of Ruggles Street to Parker Street, where the two roadways diverge to pass on both sides of the block of buildings bounded by Huntington Avenue, Louis Prang Street, The Fenway and Museum Road, in order to preserve the Museum School, St. John of Damascus Church and Parish House, and a block of apartments. At Huntington Avenue where the two roadways diverge, two separate tunnels, one for each roadway, are provided so as to maintain over the expressway the collector-distributor road system which is continuous from Massachusetts Avenue to Commonwealth Avenue. Immediately after passing the Museum School, the separate roadways converge to pass under Park Drive and Brookline Avenue. This location then ascends after passing Brookline Avenue, so as to pass over relocated Muddy River, the Highland Branch of the MTA, and Beacon Street just west of Park Drive. The Beacon Street subway portal is relocated approximately 500 feet westerly to eliminate a collector-distributor road and mass transit grade crossing. The Recommended Location from Beacon Street across Commonwealth Avenue to the Charles River was described earlier for the Charles River crossing.

Alternate Design I involves a variation in the design of the interchange with the Southwest Expressway, and differs from the Recommended Location in this area in that it crosses over Columbus Avenue, Tremont Street, and the New York, New Haven and Hartford Railroad. Most of this interchange would therefore be elevated, instead of depressed as it is in the Recommended Location. Alternate Design I has the same horizontal alignment as the Recommended Location in the Southwest Expressway interchange area. However, it presents a different horizontal alignment in the vicinity of Wentworth Institute and the Museum of Fine Arts than does the Recommended Location, which diverges and passes to each side of the block bounded by Museum Road, the Fenway, Louis Prang Street, and Huntington Avenue. This design maintains a narrow median with both roadways side-by-side, and passes directly through this block, requiring all structures in the block to be demolished. This location remains depressed after passing under Brookline Avenue, so as to pass under the Highland Branch of the MTA and Beacon Street, where it joins the tunnel crossing of the Charles River, Alternate Design I at the river.

Alternate Design II is the same as the Recommended Location with a similar vertical alignment at Beacon Street, except for a difference in horizontal alignment in the vicinity of Wentworth Institute and the Museum of Fine Arts. This location passes through the parking lot of the Museum of Fine Arts, leaving all structures in the above-mentioned block intact, but passing very close to the Museum. It then connects to the Alternate Design II for the Charles River crossing.

The Alternate Location of the Inner Belt in Boston is along Tremont Street and Francis Street. This location begins at the southerly end of the Central Artery, passes over Massachusetts Avenue and beneath Washington Street at Ruggles Street, just north of the Dudley MTA Station. This location becomes parallel to Dudley Street as it enters the interchange with the Southwest Expressway, located along Washington Street. The interchange is planned so as to avoid the First Church in Roxbury at John Elliot Square, and the MTA storage and maintenance facilities south of Dudley Station. This location then passes over Roxbury Crossing and the New York, New Haven & Hartford Railroad, and parallels the west side of Tremont Street in a side hill location. At Roxbury Crossing, extensive improvements to the surface street system, including a separate underpass of the area for Columbus Avenue through-traffic, are necessary in order to handle the traffic movements effectively. The Alternate Location passes under St. Alphonsus Street and Huntington Avenue between Francis Street and Fenwood Road, thence under Brookline Avenue and over Muddy River to a location parallel to Kent Street and along the west side of Longwood Towers in Brookline. At the intersection of Brookline Avenue and The Riverway, extensive facilities are required to pro-

TABLE B-I
INNER BELT
SUMMARY OF PHYSICAL EFFECTS

NUMBER IN CATEGORY

CITY OR TOWN:	Recommended Location						Alternate Design I		Alternate Design II		Alternate Location					
CATEGORY	Boston	Brookline	Cambridge	Somerville	Boston (Charlestown)	Totals	Boston	Brookline	Boston	Brookline	Boston	Brookline	Cambridge	Somerville	Boston (Charlestown)	Totals
Use of Structures																
Residential	534	21	501	197	10	1,263	463	46	530	47	831	31	48	204	43	1,157
Retail	59	1	117	27	3	207	52	8	58	8	184	11	17	16	—	228
Wholesale	4	—	6	2	—	12	3	—	4	1	15	1	16	6	—	38
Business	3	3	10	—	—	16	6	1	7	1	28	2	1	1	—	32
Service	23	3	38	2	1	67	28	3	25	9	69	2	6	8	1	86
Institutions	22	—	7	1	—	30	23	—	24	—	29	1	6	1	—	37
Industry	24	—	23	30	4	81	24	1	23	—	34	—	25	18	1	78
Recreation	3	—	2	1	—	6	3	—	3	—	2	1	—	1	—	4
Other Data																
Vacant Lots	345	2	9	2	—	358	328	2	324	9	276	4	1	1	1	283
Households Displaced	1,606	83	1,541	589	28	3,847	1,484	173	1,757	204	2,378	116	131	542	70	3,237
Employees Displaced	763	21	945	642	121	2,492	787	30	768	37	1,380	316	2,171	979	10	4,856
Tax Loss*	$781,210	$11,204	$391,100	$231,080	$27,210	$1,441,804	$899,022	$79,847	$1,032,076	$93,219	$885,270	$116,151	$347,904	$256,504	$17,080	$1,622,909

*Based on 1961 tax rates.

vide for the interchange of traffic between these two streets and the frontage roads of the expressway, as well as the local access ramps. After crossing Muddy River, the Alternate Location is in a depressed section until it reaches Beacon Street, which it crosses on viaduct as it proceeds northerly in a location parallel to and east of Amory Street to join with the location of the Charles River crossing.

DESCRIPTION AND ANALYSIS OF OTHER LOCATIONS STUDIED

In addition to the Recommended and Alternate Locations, other alternative locations were studied, including many combinations of interconnections between these alternatives and the Recommended and Alternate Locations. There follows a brief description of two of the alternative locations considered.

ALTERNATIVE LOCATION A

This location is completely elevated from the Southwest Expressway interchange to Beacon Street, in the same horizontal location as Alternate Design II of the Recommended Location. This alternative was discarded, because it offered no particular economic advantage over a depressed roadway, as a consequence of the poor foundation conditions.

ALTERNATIVE LOCATION B

This location is depressed from the Southwest Expressway interchange to Beacon Street, and passes west of the Museum School and St. John of Damascus Church, with its center-line along the center of Louis Prang Street. This location would require extensive alteration of major utilities without concurrent advantages to offset these additional costs, and was therefore discarded.

ANALYSIS OF RECOMMENDED AND ALTERNATE LOCATIONS

TRAFFIC SERVICE

The Recommended Location in Boston, between Massachusetts Avenue and the Charles River crossing, provides fourteen ramps, consisting of ten parallel-type ramps to and from the Inner Belt and four ramps serving the Southwest Expressway directly. The traffic assignments to this section of the Inner Belt reflect major desires to and from the north and northwest. To serve these desires, three on-ramps and three off-ramps are provided. Service to the Southwest and Southeast Expressways and the Central Artery consists of two on-ramps and two off-ramps. Within the recommended direct-connector interchange with the Southwest Expressway, two off-ramps from the Southwest Expressway are provided to serve traffic having destinations inside the Inner Belt. Two southbound on-ramps are provided: one from the frontage road and one from Columbus Avenue for the return movement. Direct connections are provided to the Massachusetts Turnpike, for service to and from the western corridor. The Alternate Designs to the Recommended Location provide essentially identical traffic service to that provided by the Recommended Location.

An extensive and essential collector-distributor surface road system is recommended between Massachusetts Avenue and Beacon Street to intercept and distribute the high ramp-volumes to the existing arterial streets. To realize the maximum benefits from the Inner Belt and Expressway System, these connecting arterial streets will require alterations and improvements to increase their operational efficiency, in order to accommodate the high-volume ramp traffic and the resulting turning movements.

The Alternate Location provides comparable local interchanges to serve the major traffic desires. Twelve parallel on- and off-ramps provide service to the Inner Belt, including eight for service to and from the north and west, and four for service to and from the south and east. At the direct-connector interchange with the Southwest Expressway, intown on- and off-ramp service is provided, connecting the Southwest Expressway to Tremont Street and Columbus Avenue for trips having origins or destinations in the Back Bay and South End. Direct connections to the Massachusetts Turnpike are provided prior to crossing the Charles River, for service to and from the west. As with the Recommended Location, a continuous collector-distributor surface road system is included as shown on the Basic Design Exhibits, between Massachusetts Avenue and Commonwealth Avenue, to provide adequate interception and distribution of ramp traffic.

Although the volumes of traffic assigned to the Recommended and Alternate Locations of the Inner Belt in Boston and Brookline are approximately the same because of corresponding capacity limitations, the Recommended Location of the Inner Belt provides for superior comprehensive traffic service in Boston and Brookline, as compared with the Alternate Location, for the following reasons:

a. The Recommended Location is closer to the downtown core of the city, thereby reducing the length of travel on local streets for a greater number of vehicles.
b. The Recommended Location permits the collector-distributor roadways to intercept three more arterial streets than does the Alternate Location.
c. The Recommended Location complements the existing street pattern, whereas the Alternate Location crosses several major points of existing traffic congestion, and its local-access ramps tend to add to this congestion in spite of the provision of collector-distributor roads.
d. The Recommended Location provides a more even distribution of ramp volumes, which results in less congestion of the local street system.

PHYSICAL AND FUNCTIONAL EFFECTS

A comparison of the physical effects of the Recommended and Alternate Locations and the Alternate Designs to the Recommended Location in Boston and Brookline is presented in Table B-I. This comparison shows that the Recommended Location results in far less displacement of families and businesses than the Alternate Location. The Recommended Location offers far greater advantages than the Alternate Location for integration of the Inner Belt with present and future land-use developments in both Boston and Brookline. Both locations in Boston are within General Neighborhood Renewal Plan areas of the Boston Redevelopment Authority. A major part of the Recommended Location passes through an area programmed for clearance, and the balance is either a depressed or tunnel section through The Fenway, causing no displacements. A major part of the Alternate Location in Boston passes through an area programmed for rehabilitation, and its entire length in Brookline passes through residential property of very high value.

In excess of eighty percent of all displacements caused by the Recommended Location occur in the Renewal Area between Massachusetts Avenue and Columbus Avenue, which is designated for clearance, and therefore displacements produced by the Recommended Location of the Inner Belt would inevitably occur under the urban renewal program. In addition, over twenty-two percent of all land to be acquired for the Recommended Location in Boston and Brookline is presently unimproved and vacant. The Recommended Location of the interchange with the Southwest Expressway is in an area which contains many abandoned structures which have been condemned by the City of Boston. Over ten percent of this land has already been acquired by the City of Boston through condemnation proceedings, and over thirty percent of the land is presently vacant.

For purposes of identification, any structure housing a church or religious body has been designated as an institution, and a large number of these would be taken by each of the Inner Belt locations. However, in the case of the Recommended Location, many of these institutions which are being used in whole or part by a small group as a church or meeting place, are former stores or other commercial-purpose buildings with small replacement value. The following institutional-type structures are included among those taken by the Recommended Location: St. Francis DeSales Church, Roxbury Neighborhood House, Fourth Methodist Episcopal Church, St. Cyprian's Episcopal Church, Asa Gray and Sherwin Schools, Salvation Army Neighborhood Center on Vernon Street, and Massachusetts Society for Prevention of Cruelty to Children building on Parker Street.

The Alternate Designs to the Recommended Location produce physical effects similar to the Recommended Location except that:

a. Alternate Design I requires the displacement of all structures in the block bounded by Louis Prang Street, Huntington Avenue, Museum Road and The Fenway, and therefore results in taking the Museum School, St. John of Damascus Church and Parish House, and a large block of apartments. This design also includes a tunnel crossing of the Charles River for the Inner Belt, and the connection of the Massachusetts Turnpike to and from the north for the Inner Belt crosses the Charles River on a two-level bridge. While this design has some obvious aesthetic advantages, as noted later, there is a rather severe cost disadvantage.
b. Alternate Design II results in a minimum of displacements in the vicinity of the Museum of Fine Arts, since it passes through the Museum parking lot. The interchange with the Massachusetts Turnpike is located in Boston and Brookline entirely over land; thus a greater number of structures are affected than by the Recommended Location.

The Alternate Location tends to divide similar present and proposed land-use patterns. The Alternate Location interchange with the Southwest Expressway is in an area programmed for rehabilitation under urban renewal, and some of the structures to be taken for the expressway would have been preserved under urban renewal. Furthermore, the Alternate Location generally disrupts this entire area and makes difficult the future development

of the area under urban renewal. The section of the Alternate Location along Tremont Street occupies valuable property, which has been considered ideal for possible future expansion of the hospital complex surrounding the Harvard Medical School, and also for general business development.

The Alternate Location in Brookline divides areas of similar land use and tends to disrupt future use and development of the area. Due to the topography in this area, it would be expensive to construct the Alternate Location as a depressed expressway, and a considerable increase in the width of taking would be required, which accentuates the physical separation of the easterly part of Brookline. The Alternate Location would have a decidedly adverse effect on the Town of Brookline, both in initial land requirements and future development.

The number of institutional structures taken by the Alternate Location is considerable, and includes the Roxbury Neighborhood House, Timilty, Dillaway, Bacon, and Davis Schools, a Police and Fire Station, St. James Episcopal Church, Boys' Club of Boston, Roxbury Court House, Roxbury Post Office, St. Francis DeSales Church and School and the Convent on Vernon Street, Deaconess Hospital Nurses Home, two buildings of Wheelock College, and St. Dominic's Institute in Brookline.

The total cost of right-of-way acquisition and the total assessed valuation of property taken are each approximately $5.8 million less for the Recommended Location than for the Alternate Location. The Alternate Location would take $500,000 more in tax-exempt property than the Recommended Location. The resulting short-term annual tax loss for Boston and for Brookline is approximately $100,000 less in each of these communities for the Recommended Location than for the Alternate Location.

The Recommended Location results in a minimum of dislocations and disruption of existing land use, and provides maximum opportunity for the future development of the area. Between Parker Street and Brookline Avenue, the combination of depressed and tunnel sections of the Recommended Location preserves the integrity of the adjacent institutions. The total impact of the Recommended Location on Boston and Brookline is relatively minor, in that proposed clearance under urban renewal would result in nearly identical physical effects. The over-all effect of the Recommended Location on Boston and Brookline would be a considerable net gain in property values resulting from the functional effect of vastly improved accessibility. The Inner Belt in its entirety will produce an increase in accessibility throughout the Metropolitan Area, and although the largest share of the gain in property values due to the increased accessibility will accrue to Boston, the Town of Brookline will also show substantial gains in property values.

COST ANALYSIS

The summary of costs of the Recommended and Alternate Locations of the Inner Belt are presented in Table B-II, together with a summary of the costs of Alternate Designs I and II for the Recommended Location. In addition to this summary, cost data was prepared to enable a comparison of costs for those sections of the Recommended and Alternate Locations between common points. The following costs are presented for the Inner Belt from Massachusetts Avenue, Boston, to the Cambridge side of the Charles River:

	Recommended Location	Alternate Location
Right-of-Way Costs	$ 9,519,000	$15,339,000
Construction Costs*	74,664,000	59,705,000
Total Costs	$84,183,000	$75,044,000

*Including Demolition, Engineering, and Contingencies.

The Recommended Location in Boston and Brookline would cost $15 million more to construct than the Alternate Location in Boston and Brookline. The major factor influencing this cost differential is that the Recommended Location is generally depressed whereas the Alternate Location is generally elevated. The Recommended Location is depressed between Washington Street and Brookline Avenue, and in the vicinity of the Museum of Fine Arts is covered as a tunnel section, due to its close proximity to the many fine institutions along Ruggles Street and The Fenway. A depressed location would preserve the character of the area and maintain its integrity, whereas an elevated location would tend to separate the various institutions and detract from their integrated function and aesthetic appearance.

The cost differential between the two locations is further accentuated by factors which generally favor an elevated expressway along the Alternate Location, and are unfavorable to a depressed expressway along the Recommended Location. Because the Recommended Location is depressed, several large utilities must be relocated, at a cost of $2.5 million. The high water-table along the Recommended Location requires costly construction methods and use of expensive waterproofing materials, whereas the favorable foundation conditions along the Alternate Location result in a more economical type of construction, even though considerable amounts of rock excavation are involved.

The cost of construction of the Alternate Designs for the Recommended Location is approximately the same as that for the Recommended Location, except in the case of Alternate Design I between Beacon Street in Boston and Massachusetts Avenue in Cambridge, Cost Section No. 3 in Table B-II. This Design involves a tunnel crossing of the Charles River and costs approximately $47 million more to construct between these limits than does the Recommended Location, primarily due to the greater cost of the tunnel, the considerable amount of relocation required for the Massachusetts Turnpike, and the large cost associated with providing depressed connections to the Turnpike from the Inner Belt to the south.

The cost of acquisition of the right-of-way would be $5.8 million less for the Recommended Location than for the Alternote Location. This difference results from the greater length, and the higher density and greater value of structures, along the Alternote Location. The assessed valuation of all property in Boston and Brookline necessary for the construction of the Recommended Location is $8,002,000 and for the Alternate Location $13,936,000.

ROAD-USER BENEFIT ANALYSIS

The results of the road-user benefit analyses, described in Part II and applied to the Recommended and Alternate Locations of the Inner Belt in Boston and Brookline, are shown in Table B-III. The road-user benefit values more than justify the construction of either location as economically sound. The road-user benefit ratio

TABLE B-II
INNER BELT
PROJECT COSTS

In Thousands of Dollars

Section Number	Construction Costs In thousands: Structures	Earthwork	Pavement	Utility Relocation	Miscel-laneous	Total Construction Cost	Demolition Cost	Construction Cost Plus Demolition	Engineering and Contingencies	Right-of-Way Costs, Total Fair Market Value	Total Costs
RECOMMENDED LOCATION											
1	$ 18,125	$1,100	$ 713	$1,075	$1,003	$ 22,016	$ 906	$ 22,922	$ 3,438	$ 3,233	$ 29,593
2	17,434	89	444	2,743	1,711	22,421	204	22,625	3,394	4,842	30,861
3	27,133	500	315	570	387	28,905	499	29,404	4,411	5,340	39,155
4	3,941	385	744	155	190	5,415	346	5,761	864	3,670	10,295
5	14,886	510	389	180	469	16,434	892	17,326	2,599	5,356	25,281
6	26,976	40	40	501	190	27,747	122	27,869	4,180	1,584	33,633
Totals	$108,495	$2,624	$2,645	$5,224	$3,950	$122,938	$2,969	$125,907	$18,886	$24,025	$168,818
ALTERNATE DESIGN I											
1	$17,359	$ 706	$ 565	$ 528	$ 942	$ 20,100	$ 851	$ 20,951	$ 4,190	$ 2,999	$ 28,140
2	21,001	259	370	1,550	1,328	24,508	259	24,767	4,953	6,087	35,807
3	59,863	783	388	2,936	965	64,935	432	65,367	13,073	8,303	86,743
ALTERNATE DESIGN II											
2	$ 23,717	$ 93	$ 369	$2,899	$ 849	$ 27,927	$ 179	$ 28,106	$ 5,621	$ 5,113	$ 38,840
3	28,776	385	355	684	432	30,632	564	31,196	6,239	7,665	45,100
ALTERNATE LOCATION											
1	$ 8,472	$1,645	$1,056	$ 935	$1,460	$ 13,568	$1,206	$ 14,774	$ 2,216	$ 7,173	$ 24,163
2	11,434	2,797	720	487	446	15,884	402	16,286	2,443	4,875	23,604
3	34,994	346	299	772	536	36,947	255	37,202	5,580	7,037	49,819
4	6,923	13	43	153	81	7,213	78	7,291	1,094	2,338	10,723
5	22,312	93	203	113	343	23,064	467	23,531	3,530	4,704	31,765
6	33,120	18	125	122	331	33,716	283	33,999	5,100	2,960	42,059
Totals	$117,255	$4,912	$2,446	$2,582	$3,197	$130,392	$2,691	$133,083	$19,963	$29,087	$182,133

COST SECTIONS

1. Massachusetts Avenue to New York, New Haven & Hartford Railroad
2. New York, New Haven & Hartford Railroad to Beacon Street
3. Beacon Street to Massachusetts Avenue, Cambridge
4. Massachusetts Avenue to Hampshire Street — Recommended Location
   Massachusetts Avenue to Broadway — Alternate Location
5. Broadway to McGrath Highway
6. McGrath Highway to Prison Point Bridge

PROJECT COSTS PER MILE

	Recommended	Alternate
Number of Miles	6.2	7.2
Construction and Engineering Cost/Mile	$23,354	$21,256
Right-of-Way Cost/Mile	$ 3,875	$ 4,040
Project Cost/Mile	$27,229	$25,296

indicates a 3.9-to-one economic advantage over travel on the existing surface street network for the Recommended Location, as compared with a 4.3-to-one economic advantage for the Alternate Location. Comparison of the annual road-user benefit values for the two locations shows an incremental saving of $1 million annually in favor of the Recommended Location.

LOCATIONS IN CAMBRIDGE, SOMERVILLE, AND CHARLESTOWN

GENERAL

The Inner Belt locations in Cambridge, Somerville, and Charlestown are controlled by the Charles River crossing in the vicinity of Boston University Bridge, as previously discussed, and by the terminus of a presently-designed section of the Inner Belt in the vicinity of Prison Point Bridge in Charlestown, shown as Terminal Control Point 2 on Exhibit B-1. This is one of the seven terminal control points previously outlined in Part II. These controls, together with the urban structure of the cities, involving densely populated and complex land uses, are factors having important bearing on the selection of Inner Belt locations.

The major land-use controls in Cambridge are the Charles River recreational area, the industrial complex east of Central Square, the Central Square shopping district, the Cambridgeport, Donnelly Field and Houghton Renewal Areas, and the commercial, educational, and research institutions bordering the Charles River. In Somerville, the land-use controls are the heavily industrialized areas adjacent to the Boston and Maine Railroad yards and along the Fitchburg Division of this railroad. Residential properties intermixed with light industry occupy the area immediately north of the Somerville-Cambridge City Line. This area also includes Lincoln Park, a recreational playground for the neighborhood. Between Washington Street and Broadway, the land is used predominantly for residential purposes. In the Charlestown section of Boston, the major land-use controls are the Boston and Maine Railroad yards, and the existing and proposed industrial and commercial establishments in and around the yards and bordering Rutherford Avenue.

TABLE B-III
INNER BELT
BOSTON-BROOKLINE
ROAD-USER BENEFIT ANALYSIS

Item	Recommended Location	Alternate Location
Length, miles	2.9	3.5
Annual Road-User Benefit	$19,919,000	$18,837,000
Annual Cost of Expressway	$ 5,103,000	$ 4,371,000
Road-User Benefit Ratio	3.9	4.3

The existing street patterns in Cambridge, Somerville, and Charlestown are other major considerations in selecting locations for the Inner Belt. The collection and distribution of expressway traffic must be accomplished by the local street systems. It is important that careful consideration be given to the expected change in traffic patterns. At the present time there is a heavy volume of truck traffic in and through this area, much of which passes directly through Central Square. With the construction of the Massachusetts Turnpike interchange at Cambridge Street, Allston, and the accompanying tandem trailer and flexi-van operations, the truck traffic through Central Square will be substantially increased, thereby causing greater traffic congestion. This congestion can be relieved only by the Inner Belt, which, together with a direct-connection interchange with the Massachusetts Turnpike, will permit heavy trucking to remain on the Expressway System until a local street interchange close to its destination is reached, thereby eliminating extensive truck travel along the surface streets in Cambridge and Somerville.

The Northwest and Northern Expressways also influence the location of the Inner Belt. The location of the Northwest Expressway interchange with the Inner Belt must be compatible with land uses, street systems, the corridors for the Expressway, and with the interchange between the Northern Expressway and the Inner Belt. The Northwest Expressway interchange area is generally located within proposed urban renewal areas in Cambridge and Somerville. This location provides maximum opportunity for coordinated urban renewal planning and highway construction, and permits adequate spacing between the Northwest and Northern Expressway interchanges.

The Northern Expressway interchange can be located either in the Boston and Maine Railroad yards, or between Washington Street and Broadway north of the railroad yards. Because this interchange area is also located within proposed urban renewal areas in Somerville and Charlestown, there is maximum opportunity for coordinated planning. The location of the Northern Expressway interchange controls the location of the Inner Belt in Charlestown. Location of this interchange north of the railroad yards allows the Inner Belt to be located over the railroad siding parallel to Rutherford Avenue. However, with the location of the interchange in the Boston and Maine Railroad yards, the Inner Belt must remain in the yards from the Northern Expressway interchange to the end of a presently-designed section of the Inner Belt in the vicinity of Prison Point Bridge.

In the Alternate Location, the Northern Expressway interchange is in the area north of Washington Street, and the Northwest Expressway interchange is north of Donnelly Field. This arrangement provides sufficient spacing between these major interchanges. If the interchange with the Northern Expressway were located in the Boston and Maine Railroad yards, as in the Recommended Location, the interchange with the Northwest Expressway would have to be located south of Donnelly Field in order to maintain adequate spacing between the interchanges. Locating the Northwest Expressway interchange south of Donnelly Field was considered impracticable because of the extensive physical effects on Cambridge.

TOPOGRAPHY AND SUBSURFACE CONDITIONS

The Recommended and Alternate Locations, located within the Boston Basin, have similar general subsurface characteristics with only local variations. A relatively shallow surface-layer of fill overlies a thin stratum of fine-to-coarse sand, which in turn overlies substantial depths of blue clay. The top zone of the clay, generally not less than 10 feet in thickness, is desiccated and is relatively stiff. A deposit of glacial till varying in thickness is gen-

erally encountered below the clay deposit, overlying the bedrock. Bedrock rises irregularly but continuously toward the north, from depths of approximately 120 feet below the surface at Memorial Drive in Cambridge, to within 50 feet of the surface at the Somerville Line on Webster Avenue. In Somerville, rock continues to rise toward the north, approaching to within 10 feet of the ground surface in the vicinity of Prospect Hill, and then deepening to 30 feet in the vicinity of the Northern Expressway interchange. In the area to the west and north of the yards, deposits of sand and till generally overlie the comparatively shallow bedrock.

Shallow and localized organic deposits are present in Somerville and along the more easterly alignments in Cambridge. Beneath the shallow surface-fill, soft peat and organic silt deposits, averaging five feet in thickness, appear in the central and northern sections of the locations along the Grand Junction Branch of the New York Central Railroad.

DESCRIPTION OF RECOMMENDED AND ALTERNATE LOCATIONS

The Recommended Location in Cambridge, after crossing the Charles River just west of Boston University Bridge, parallels Brookline Street and crosses Massachusetts Avenue east of Central Square. From Massachusetts Avenue, the location continues between Columbia and Elm Streets northeasterly to an interchange with the Northwest Expressway at the Cambridge-Somerville City Line between Donnelly Field, Cambridge, and Lincoln Park, Somerville. In Somerville, the Recommended Location crosses over the Fitchburg Division of the Boston and Maine Railroad and McGrath Highway, enters the Boston and Maine Railroad yards, and runs parallel to Washington Street south of the industrial complex, to an interchange with the Northern Expressway at the Somerville-Charlestown Line. It then proceeds easterly through the railroad yards in Charlestown to the end of a presently-designed section of the Inner Belt in the vicinity of Prison Point Bridge, shown as Terminal Control Point 2 on Exhibit B-1.

The Alternate Location in Cambridge crosses the Charles River just west of Boston University Bridge, and follows the right-of-way of the Grand Junction Branch of the New York Central Railroad as an elevated double-decked structure. It interchanges with the Northwest Expressway north of Donnelly Field and continues across McGrath Highway, the Boston and Maine Railroad, and Washington Street to an interchange with the Northern Expressway. The interchange with the Northern Expressway is located between Washington Street and Broadway at the Somerville-Charlestown Line. From the Northern Expressway interchange, the Alternate Location continues as a double-decked structure over the railroad siding which serves the industrial plants along Rutherford Avenue, to the end of a presently-designed section of the Inner Belt, shown as Terminal Control Point 2 on Exhibit B-1.

DESCRIPTION AND ANALYSIS OF OTHER LOCATIONS STUDIED

In addition to the Recommended and Alternate Locations, the several alternative locations that were investigated in detail are described below.

ALTERNATIVE LOCATION A

This location, the River Street location, after crossing the Charles River continues in Cambridge as an elevated expressway across Memorial Drive. From Memorial Drive it continues east of and parallel to River Street. At the intersection of Pleasant and River Streets this alternative extends easterly, crossing Magazine and Pearl Streets, to Massachusetts Avenue at Brookline Street, where it becomes common with the Recommended Location.

This location was one of several presented at the Public Hearing of May 10, 1960. Its location in Cambridge was controlled by the interchange betweeen the Massachusetts Turnpike and the Inner Belt within the area of the New York Central Railroad yards in Allston. Subsequent to the hearing, the firm decision to extend the Turnpike into Boston made this location impracticable because of space limitations within the yards, as previously outlined. The space required for minimum rail facilities and flexi-van operations together with the Turnpike facilities, including an interchange with Cambridge Street, precludes the location of an interchange with the Inner Belt within the yards as originally studied. Because of the space limitations in the railroad yard, all locations along River Street in Cambridge were eliminated from further consideration.

ALTERNATIVE LOCATION B

This alternative, the Lee Street location, after crossing the Charles River in the vicinity of River Street, continues in Cambridge as an elevated expressway across Memorial Drive, Putnam and River Streets, and Western Avenue. After crossing Western Avenue, this location continues over Massachusetts Avenue in the vicinity of and generally parallel to Lee Street, and thence northeasterly between Maple Avenue and Fayette Street, with overpasses at Harvard Street, Broadway, Cambridge Street, and Beacon Street. After crossing Beacon Street, the location interchanges with the Northwest Expressway between Donnelly Field, Cambridge, and Lincoln Park, Somerville. From this interchange it continues over McGrath Highway and the Boston & Maine Railroad where it may become common with either the Recommended or Alternate Locations north of McGrath Highway.

In addition to the space limitations in the New York Central Railroad yards, the Lee Street location has the following additional disadvantages and was therefore discarded:

a. This location in Cambridge would pass almost entirely through an established residential area, resulting in an undesirable division of neighborhoods.
b. All traffic destined for the major traffic generating sections of eastern Cambridge would be forced to travel either through local streets, in predominantly residential and shopping areas, or through Central Square, a major business and shopping center.
c. Substantial improvements to local streets would be required to make an orderly pattern of land use and traffic distribution in Cambridge.
d. The location would be incompatible with either existing or proposed land uses in Cambridge.

ALTERNATIVE LOCATION C

This alternative, the Memorial Drive location, after crossing the Charles River in the vicinity of Boston University Bridge, extends along Memorial Drive and Commercial Avenue to the present terminus of the Central Artery. The commercial and educational de-

velopments adjacent to the river create a barrier which precludes the connection of the Northwest Expressway directly to the Inner Belt Expressway. Therefore, the Northwest Expressway would have to be extended along the corridor of the Recommended Location of the Inner Belt, in the Boston and Maine Railroad yards, to the Northern Expressway, and the resulting combined expressways extended to the end of the present design of the Inner Belt.

The location along Memorial Drive was considered unacceptable and was discarded for the following reasons:

a. The Inner Belt, in this location, could not properly function as a circumferential collector-distributor expressway, because a direct connection with the Northwest Expressway is impracticable.

b. Locating the Inner Belt along Memorial Drive would reduce the area of traffic influence of the roadway. An expressway located near the centroid of major traffic desires would have a greater beneficial influence on local traffic patterns, since local traffic would reach the expressway from both sides, rather than from only one side, as would be the case for the Memorial Drive location. The greater the volume of Cambridge traffic that can use the expressway with a minimum of travel on local streets, the more advantageous the Expressway System will be to the City of Cambridge.

c. Memorial Drive would have to be used as a collector-distributor roadway for the Inner Belt; therefore it would have to be reclassified to permit trucking. Its use as a collector-distributor would preclude its functioning as a major arterial supplementing the Expressway System.

d. By locating the Inner Belt along Memorial Drive, the length of the Inner Belt would be decreased, but the length of actual roadway required to complete the over-all Expressway System would be increased, because extensions of the Northern and Northwest Expressways would also be required.

e. This location would greatly reduce the scenic and aesthetic attractiveness of the area adjacent to the Charles River, and would decrease the value of the river for recreational purposes. Since the Charles River Basin is one of the major recreational facilities serving the entire Metropolitan Area, any reduction of its recreational and scenic value would be irreparable.

ALTERNATIVE LOCATION D

This location, the Donnelly Field location, is common to the Recommended Location from the Charles River crossing to Massachusetts Avenue. From Massachusetts Avenue this alternative extends northeasterly, passing to the east of Donnelly Field, then continuing through the Boston and Maine Railroad yards to the end of the present design of the Inner Belt, shown as Terminal Control Point 2 on Exhibit B-1.

This location requires that the interchange with the Northwest Expressway be located south of Donnelly Field, in order to provide sufficient spacing between the Northwest and the Northern Expressway interchanges. This Alternative, which is a modification of the Recommended Location, precludes the provision of adequate traffic service to Somerville and Charlestown, because it is located entirely within the railroad yards; it was therefore discarded.

ANALYSIS OF RECOMMENDED AND ALTERNATE LOCATIONS

TRAFFIC SERVICE

The Recommended Location in Cambridge, between Memorial Drive and the Northwest Expressway, provides two complete local street service interchanges. Ramps from the Northwest Expressway at the direct-connector interchange with the Inner Belt will permit maximum local service to the Cambridge area. Ramps have been provided between the Northwest Expressway and McGrath Highway to permit direct access to the East Cambridge and North Terminal areas without requiring travel on the Inner Belt. The limited distance betweeen the Northwest and the Northern Expressways precludes additional ramps in this area; however, in the vicinity of the Northern Expressway interchange, ramps to and from the south and west provide traffic service for the Somerville-Charlestown area.

Between Sullivan Square, Charlestown, and Memorial Drive, Cambridge, collector-distributor roads are designed to handle the assigned ramp volumes adequately, and to permit effective distribution to the local arterial streets. In some areas, these collector-distributor roads are improved existing streets, widened as necessary; in other sections, they are new roadways located adjacent to the Expressway.

The Inner Belt in the Recommended Location, from the Northern Expressway interchange to its terminus in the vicinity of Prison Point Bridge, is a double-decked viaduct. The large traffic desires in the Charlestown-Cambridge area for service to and from the north are accommodated by parallel ramps to a widened, rebuilt Prison Point Bridge.

The Alternate Location is a double-decked structure for its entire length. Two complete diamond-type interchanges are provided between Memorial Drive, Cambridge, and the interchange with the Northwest Expressway. On- and off-ramps from the Northwest Expressway, terminating at the Medford Street-Warren Street frontage road system, are provided to serve the northwest traffic desires in this area of Cambridge. Ramps are also provided between the Northwest Expressway and McGrath Highway, as in the Recommended Location.

Local ramp service in the vicinity of the direct-connector interchange with the Northern Expressway consists of two sets of on- and off-ramps, one set serving traffic to and from downtown Boston, and the second set serving traffic to and from the south and west. A continuous collector-distributor system is also provided in the Alternate Location to permit effective distribution of traffic between the Expressway and the local arterial streets.

The Recommended Location of the Inner Belt provides superior overall traffic service as compared with the Alternate Location for the following reasons:

a. The Recommended Location is in close proximity to the major traffic generators, thereby requiring minimum length of travel on local streets. The Alternate Location is close to the extremities of the major traffic generators, and thus requires longer travel distances on surface streets, resulting in greater local street congestion.

b. The collector-distributor system in the Recommended Location intersects more arterial and local streets than the

Alternate Location, and permits adequate distribution of the assigned ramp traffic. The intersection by the Alternate Location of only a limited number of roadways will increase traffic congestion on the arterial and local streets and proposed frontage roads.

PHYSICAL AND FUNCTIONAL EFFECTS

A comparison of the physical effects of the Recommended and Alternate Locations of the Inner Belt, as summarized in Table B-I reveals that the Recommended Location affects more households and fewer employees than the Alternate Location. The Recommended Location passes through the Cambridgeport and Donnelly Field Renewal Areas in Cambridge, the Linwood-Joy and other proposed renewal areas in Somerville, and a proposed renewal area in Charlestown. In reviewing the households affected in Cambridge, Somerville, and Charlestown it must be considered that many of the householders presently residing in these renewal areas will eventually be affected by urban renewal activities, and that the tax losses and the numbers of households displaced, jobs lost, and businesses affected by the Recommended Location are substantially offset by the fact that many of these, recorded in Table B-I, would occur under urban renewal activities.

The City of Cambridge has actively coordinated its renewal plans with the expressway location studies to obtain the maximum practicable benefits from construction of the Inner Belt. The Recommended Location serves as a desirable physical divider between the proposed Cambridgeport Renewal Area, which will be primarily developed for residential purposes, and the existing and proposed commercial and industrial areas between the Charles River and the corridor of the Recommended Location. Such a facility reduces truck traffic filtration through residential neighborhoods, and provides ready access to the industrial areas. The City of Somerville also has planned for future commercial and industrial development areas adjacent to the Inner Belt Expressway, thus capitalizing on the potential offered by the expressway construction through improved access to other sections of the Metropolitan Area. Here again, the Inner Belt is planned to act as a buffer between existing residential sections and proposed commercial and industrial development areas. As shown on Exhibit B-1, a major renewal area is generally bounded by McGrath Highway, Broadway, and Washington Street. Industrial development is proposed for the area within these boundaries, located to the east of the Expressway, adjacent to the Somerville-Boston City Line and Washington Street. There are also other areas located in the vicinity of the Expressway System that are proposed for either residential, commercial, or industrial development. In Boston, the entire Charlestown section has been designated an urban renewal area and is presently under study for renewal planning. The area within the Boston and Maine Railroad yards is expanding rapidly with industrial development and such development is expected to be further stimulated by construction of the Inner Belt.

The Recommended Location is expected to stimulate the rejuvenation of the Central Square business area in Cambridge, and the proposed and existing commercial and industrial development areas in Somerville and Charlestown, by providing convenient access to the Expressway System. Local employment, current renewal proposals, and accessibility to other sections of the Metropolitan Area provide necessary attractions to sustain these developments.

The Alternate Location has little effect on the urban structure of either Cambridge, Somerville, or Charlestown. The majority of the households affected in this location are also located basically within proposed renewal areas, many of which, as in the case of the Recommended Location, would have been affected anyway by urban renewal activities. Since the Alternate Location is essentially confined to the existing railroad corridor, it displaces fewer households than the Recommended Location. However, this location, in order to provide a continuous collector-distributor system, does have the disadvantage of disrupting commercial and industrial activities in Cambridge adjacent to the railroad. The concern of city officials to the recent loss of other manufacturing establishments is indicative of their probable reaction over the potential employment loss resulting from locating the Expressway along the railroad.

Cambridge has recently filed for approval for the expansion of the Cambridgeport Renewal Area to include the commercial and industrial area between Brookline Street and the railroad, and approval would provide additional vitally-needed areas for commercial and industrial expansion. Since the City is actively engaged in a program of commercial and industrial expansion, the development of transportation advantages, created by the Expressway System, will provide a strong and forceful attraction for these activities to remain in Cambridge.

It is possible to exchange the Recommended and Alternate Locations of the Northern Expressway interchange with either the Recommended or Alternate Locations of the Inner Belt in Cambridge. However, if the Recommended Location of the Northern Expressway interchange is connected to the Alternate Location of the Inner Belt in Cambridge, the Northwest Expressway interchange must be located to the south side of Donnelly Field, in order to maintain the required spacing between the two directional interchanges. By shifting the Northwest Expressway interchange to the south of Donnelly Field, a sizable section of Cambridge, including the proposed Donnelly Field Renewal Area, would be contained between the Somerville City Line and the Northwest Expressway.

Cambridge, Somerville, and Boston are intensely interested in the successful completion of their respective renewal programs. Early construction of the Inner Belt and Expressway System presents an opportunity for these cities to undertake comprehensive renewal programs effectively, and to realize their over-all community objectives. The structure of the cities will remain essentially unchanged; however, with several areas rebuilt and local street congestion reduced, the opportunities for the successful completion of their renewal programs will be greatly improved.

Vigorous programs of commercial and industrial redevelopment, coordinated with highway construction, which will provide vastly improved access to transportation arteries, will enable these cities to compete favorably for their share of the expanding economy. Increased access to transportation arteries will also enable existing activities to consolidate their competitive positions. Because of improved access to a transportation network that will link all the major cities in the Boston Metropolitan Area and in the United States, land values will increase throughout the entire area and in particular in Central Square, in the existing industrial areas in East Cambridge, in the area between Brookline Street and the

New York Central Railroad, in the Boston and Maine Railroad yards, in the Sullivan Square area, and along Rutherford Avenue. Although an immediate reduction in taxable properties will have a temporary effect upon these cities, the currently-planned comprehensive renewal programs, the increased employment resulting from commercial and industrial expansion undertaken in response to these programs, and the increased accessibility afforded by the Expressway System, will actually strengthen the communities tax bases through more productive and economical use of existing land, thereby providing for a better future economic balance.

COST ANALYSIS

The summary of costs of the Recommended and Alternate Locations of the Inner Belt are presented in Table B-II. In addition to this summary of costs, cost data was prepared to enable a comparison of costs for those sections of the Recommended and Alternate Locations between their common points. The following costs are presented for the northern side of the Charles River to a point east of McGrath Highway, where the Recommended and Alternate Locations cross, and thence to the Prison Point Bridge, at Terminal Control Point 2.

Charles River to Vicinity of McGrath Highway

	Recommended Location	Alternate Location
Right-of-Way Costs	$ 13,206,000	$ 11,305,000
Construction Costs*	41,729,000	59,973,000
Total Costs	$ 54,935,000	$ 71,278,000

Vicinity of McGrath Highway to Prison Point Bridge

	Recommended Location	Alternate Location
Right-of-Way Costs	$ 1,300,000	$ 2,443,000
Construction Costs*	28,400,000	33,368,000
Total Costs	$29,700,000	$ 35,811,000

*Including Demolition, Engineering, and Contingencies.

Summary of Costs: Charles River to Prison Point Bridge

	Recommended Location	Alternate Location
Right-of-Way Costs	$ 14,506,000	$ 13,748,000
Construction Costs*	70,129,000	93,341,000
Total Costs	$ 84,635,000	$107,089,000

The following conditions influence the construction costs of the Inner Belt in Cambridge, Somerville, and Charlestown.

Foundation requirements for the Recommended and Alternate Locations present no unusual problems. Since both locations are generally within the Boston Basin, where the blue clay deposits are prevalent, the costs of the foundations for all structures are based upon the use of pile construction, except in the area immediately north of Washington Street on the Alternate Location, where soil conditions are generally such that spread footings could be used.

The Recommended Location is designed as an earth embankment with provision for the planting of shrubs and trees for the increased safety of the road users, and to reduce the noise level and screen the sight of moving vehicles from the adjacent areas. Bridges and viaducts are provided as required to span existing streets and railroads which must remain open. That section located within the Boston and Maine Railroad yards is designed as a double-decked viaduct.

The Alternate Location is predicated on constructing the expressway over the Grand Junction Branch of the New York Central Railroad. To accomplish this, a double-decked viaduct is necessary for the entire length, from the Charles River to the vicinity of Prison Point Bridge. It is also necessary to reconstruct the New York Central Railroad trackage from Memorial Drive to the Cambridge-Somerville City Line. Long viaduct ramps are required to provide service to the top deck, which must be approximately sixty feet above existing ground in order to provide for rail facilities beneath the viaduct.

TABLE B-IV
INNER BELT
CAMBRIDGE-SOMERVILLE-CHARLESTOWN
ROAD-USER BENEFIT ANALYSIS

Item	Recommended Location	Alternate Location
Length, miles	3.3	3.7
Annual Road-User Benefit	$23,964,000	$21,945,000
Annual Cost of Expressway	$ 4,834,000	$ 6,159,000
Road-User Benefit Ratio	5.0	3.6

ROAD-USER BENEFIT ANALYSIS

The road-user benefit analyses for the Recommended and Alternate Locations of the Inner Belt in Cambridge, Somerville, and Boston (Charlestown) are shown in Table B-IV. The road-user benefit values more than justify the construction of either the Recommended or Alternate Locations as economically sound. However, the values show an economic advantage in favor of the Recommended Location. The road-user benefit ratio, which compares travel on the new facility to existing street travel, shows a five-to-one economic advantage in using the Recommended Location as compared with travel on the existing streets. The benefit ratio for the Alternate Location shows a 3.6-to-one economic advantage. Comparison of the annual road-user benefit values for the two locations shows an incremental direct saving in favor of the Recommended Location of $2.0 million per year for the road users.

SUMMARY

At the present time, the Expressway System for Metropolitan Boston is only partially complete and the mass transit system is inadequate, and therefore the existing streets and expressways in the Core Area do not effectively provide adequate traffic service for those who desire to travel into and within the Core Area to conduct business, to purchase goods and services, and to attend recreational and educational facilities. This traffic must now use congested surface streets which pass through high-density commercial and residential areas, or use expressways already carrying capacity volumes. The completion of expressway projects currently under construction, although part of the Expressway Sys-

tem, such as the Massachusetts Turnpike, Interstate Route 93, and reconstruction of Route 2 to Alewife Brook Parkway, will only partially relieve congestion, since for the most part the points of congestion will be shifted to new locations until such time as the entire Expressway System is completed. The completion of redevelopment projects currently under way, such as the Prudential Center, the Government Center, the West End, the New York Streets and Linwood-Joy Projects, as well as other renewal projects in the planning stage, will attract additional volumes of traffic into the Core Area in the near future. Without the completed Expressway System, the anticipated increases in population, employment and motor-vehicle use will aggravate present problems of traffic congestion to the point that many of the traffic generators would relocate outside the Core Area to obtain the accessibility necessary to maintain their competitive positions.

Completion of the Inner Belt will:

a. Provide an inter-connection for the Expressway system so that the full potential of each radial expressway will be realized.
b. Function as a collector-distributor of traffic in the Core Area, and thus deliver traffic close to its destination and provide a more even distribution of traffic through the Core Area.
c. Reduce local street traffic, particularly trucks, by removing through-travel, thus vastly improving the accessibility and environment of business, commercial, industrial and residential areas of the core cities.
d. Provide a stimulus for public redevelopment and private development and expansion, by virtue of the tremendous economic advantage gained through increased accessibility.
e. Increase the real value of all properties, by providing ready access to all parts of the Metropolitan Area and beyond.
f. Provide total direct savings in excess of $40 million annually to those using the Expressway System instead of existing streets.

The Recommended Location of the Inner Belt has the following advantages as compared with the Alternate Location:

a. Provides the greater traffic service, because it intercepts more arterial streets, and is more centrally located with respect to the major traffic generators. Its collector-distributor roadways are, in effect, new streets which complement the existing street network, and the local access ramps are more evenly spaced, thus permitting a more efficient distribution of traffic.
b. Creates less disruption of the communities through which it passes, and affords greater opportunity for redevelopment and integration of adjacent land uses with the advantages of proximity to the expressway.
c. Results in the smaller cost of right-of-way and construction, displaces fewer structures in all categories except residential use, displaces over 2300 fewer employees, and results in a smaller total tax loss to the communities through which it passes.
d. Results in a $3 million greater annual benefit to the road-user with a smaller annual cost to the taxpayer.

The Expressway System must be completed promptly to relieve traffic congestion on the existing streets to permit accessibility by vehicular travel for those trips which are vital to the economic activity of the entire Metropolitan Area. Without an expressway system to remove this congestion from the local streets, business, commercial and industrial establishments will continue to be penalized, commerce and trade will be stifled from traffic strangulation, and the economic potential of the Core Area will be severely restricted. Full cooperation of public agencies at the federal, state, and local levels, and with private enterprise, will be required so that the highway construction program recommended herein will produce the maximum possible benefits to the Boston Metropolitan Area.

SECTION 2 – THE SOUTHWEST EXPRESSWAY

GENERAL

Interstate Route 95, when completed, will serve the entire eastern seaboard with a limited-access expressway from Houlton, Maine to Miami, Florida. The Southwest Expressway will be a part of this interstate route. The southerly control point at the intersection of Route 128 has definitely been established, by previous studies, to be just east of the Route 128 Railroad Station at a point adjacent to the Neponset River. This is Terminal Control Point 3 of the seven terminal control points indicated in Part II and shown on Exhibit L-1. The location of the northerly control point, the interchange with the Inner Belt, is recommended as a result of this Study to be in the lower Roxbury section of Boston between Woshington Street and Tremont Street at Madison Park. There are no adequate existing major thoroughfares connecting these two control points of the Southwest Expressway. All streets and thoroughfares which serve this quadrant of the Boston Metropolitan Area have either one of two serious limitations as follows:

a. Narrow, two-lane, heavily congested streets, such as Hyde Park Avenue, Washington Street, and Centre Street, through high-density residential and commercial areas.

b. Major four-lane thoroughfares which do not offer a continuous route into Boston, and which are also used in part by traffic moving into Boston from the west. These thoroughfares pass through points of heavy traffic congestion or areas of high-density commercial use. Blue Hill Avenue, Columbia Road, Veterans of Foreign Wars Parkway, Jamaicaway, American Legion Highway, Truman Highway and Columbus Avenue are examples of thoroughfares in this category.

The main line of the New York, New Haven and Hartford Railroad extends in a direct line between these two control points and occupies the most favorable connecting natural or topographic avenue. The area on each side of the railroad contains many hills, abrupt changes in elevation, ledge outcroppings and other difficult topographic features which have an important bearing on construction costs and consequently on location selection.

The corridor of study contains numerous large land-use complexes which have an important bearing on the location of the expressway. Major complexes in the area of the Southwest Expressway location are the Readville Industrial Area, Cleary Square, Forest Hills Cemetery, Mount Hope Cemetery, Franklin Park, Arnold Arboretum, Notre Dame Academy, New England Hospital for Women, Roxbury Crossing, and the business areas around the Forest Hills and Dudley Street MTA Stations.

TOPOGRAPHY AND SUBSURFACE CONDITIONS

The Southwest Expressway corridor is a shallow trough formed by an arm of the Boston Basin at its northern end and the Neponset River Valley to the south, separated by a shallow ridge approximately midway between Hyde Park and Roslindale. All locations studied cross and recross the rim of this trough, resulting in marked and rapid changes in subsoil character in both the horizontal and vertical directions along each alternative location. Within the Neponset River flood plain, the soil strata consist typically of soft peat, underlain by alluvial sands and silts of varying density and thickness. The peat reaches a maximum thickness of approximately fifteen feet in some areas of the Neponset Meadows, but its average thickness is approximately five feet. Total depth to bedrock in this valley probably does not exceed thirty feet, based upon previously drilled borings.

In Roslindale, in the area where the alternatives cross Cummins Highway and reach the southerly extremity of the arm of the Boston Basin mentioned above, the overburden generally consists of thirty to fifty feet of dense sand and gravel with pockets of peat and miscellaneous fill at the surface. The water table is near the surface in this area. Excavation of the peat to moderate depths will be required where encountered.

To the east and west of the general axis of the locations studied, between Forest Hills and Roxbury Crossing, the topography is dominated by rather steep ridges having a general north-south orientation. The northern boundary of these ridges is immediately south of the Recommended Inner Belt interchange location and is formed by the isolated knolls of Washington Park, Highland Park and Parker Hill. These knolls mark the edges of the typical clay and till deposits of the Boston Basin. Where the bedrock is not exposed on these ridges, it is covered with a thin sheet of till. In turn, the till is covered in some areas by a sand stratum reaching a maximum thickness of about twenty feet. Construction in this area will require considerable rock excavation in those cases where the expressway profile is established below the existing ground surface.

North of Roxbury Crossing, in the area of the Inner Belt interchange at Madison Park, the typical Boston Basin soils strata are encountered. The surface layer consists of miscellaneous fill and sand, underlain in turn by various depths of assorted granular materials and occasionally trapped pockets of soft peats and silts, and then by the blue clay deposit varying in thickness from 50 to 100 feet. The upper layer of this deposit consists of a stiff crust of desiccated and weathered clay. Below the clay deposit is glaciol till laid upon the bedrock floor. As in other locations within the Boston Basin, the ground-water table is relatively high, situated above the clay deposit.

LOCATIONS STUDIED

While numerous locations and combinations of locotions for the Southwest Expressway were developed to the point where clear-cut comparisons could be made, only eight locotions merited further investigation and development of all factors before a selection of the Recommended and Alternate Locations could be made. These eight basic locations are shown on Exhibits B-2 and B-3, and are referred to hereinafter os follows:

Recommended Location
Alternate Location
Alternative Location A
Alternative Location B
Alternative Location C
Alternative Location D
Alternative Location E
Alternative Location F

DESCRIPTION OF RECOMMENDED AND ALTERNATE LOCATIONS

Major topographic features and large land-use complexes are key factors in the selection of locations for the Southwest Expressway. The Southwest Expressway from Route 128 northward to a point just east of Readville is confined to the valley of the Neponset River by the rugged terrain of the Blue Hills and Stony Brook Reservations. North of Readville, there are two practicable locations, the Recommended and Alternate Locations.

The Recommended Location extends from the interchange with Route 128, Terminal Control Point 3 on Exhibit B-2, northward across the Neponset River Reservation to the Neponset Valley Parkway, where it turns northwestward to cross the New York, New Haven & Hartford Railroad tracks, thence parallels the railroad to a point just south of Roxbury Crossing, where it crosses the tracks to the east and passes between Roxbury Crossing and Highland Park, thence to the Madison Park interchange with the Inner Belt.

The Alternate Location also extends from the interchange with Route 128, and is common with the Recommended Location until it is north of the Neponset Valley Parkway, where it crosses the Midland Division of the New York, New Haven & Hartford Railroad, and parallels the railroad and the Neponset River until it turns northwestward to parallel Huntington Avenue in Hyde Park, thence through Barry Quarry to cross Cummins Highway at American Legion Highway, continuing northwestward until it becomes parallel to Hyde Park Avenue, thence continuing to Washington Street at Forest Hills. Along Washington Street it is depressed, with sufficient space provided in the median for possible rapid transit facilities, and at Cedar Street it interchanges with the Alternate Location for the Inner Belt.

DESCRIPTION AND ANALYSIS OF OTHER LOCATIONS STUDIED

In addition to the Recommended and Alternate Locations, other alternative locations were studied, including many combinations of interconnections between alternatives. Each of the alternatives can be considered as interchangeable at common points of crossing. The following comprises a brief description of the locations which were studied and determined to be less advantageous than the Recommended and Alternate Locations.

ALTERNATIVE LOCATION A

Location A crosses the main-line tracks of the New Haven Railroad south of Readville instead of north of Readville, and therefore parallels the tracks for a greater distance than does the Recommended Location. The cost of providing an adequate interchange with the Neponset Valley Parkway is excessive for this location. The expressway has to be sufficiently elevated to pass over the Parkway which in turn passes over the railroad, thereby requiring extensive viaduct construction. The ramps connecting to the Parkway could not be located so as to provide adequate service, due to the proximity of the railroad and the unusually poor alignment of the Parkway. The Westinghouse Electric Company Plant is seriously impaired by the loss of its parking facilities and railroad siding. Location A was not considered advantageous, due to its cost and inferior traffic service, and was therefore discarded.

ALTERNATIVE LOCATION B

Location B utilizes that part of Location A south of the Neponset Valley Parkway and then passes west of the Westinghouse Plant to rejoin the Recommended Location along the railroad at a point west of Cleary Square. This location has some of the disadvantages of Location A; however, it does avoid the Westinghouse Plant. Location B requires the taking of a number of relatively new homes in order to provide an adequate interchange with the Parkway. Additional homes would be taken west of the Hyde Park Railroad Station, resulting in a total of approximately 100 more homes being taken than for the Recommended Location. This location was considered unacceptable due to the large number of displacements and inferior traffic service, and was therefore discarded.

ALTERNATIVE LOCATION C

Location C utilizes parts of Locations A and B and continues northwestward to by-pass the residential area west of Cleary Square. This location does not involve taking as many homes as Location B; however, it does pass through a section of the Stony Brook Reservation, takes part of the George Wright Municipal Golf Course, is immediately adjacent to the Home of the Little Flower Orphanage, traverses extremely difficult terrain which would result in maximum expressway grades, and requires considerable amounts of rock excavation. Adequate connections to existing arterial streets could not be made economically, since this location would not intercept the street pattern in a favorable location. Location C was considered unacceptable.

ALTERNATIVE LOCATION D

Location D leaves the Alternate Location just south of Cummins Highway and proceeds northward until it becomes common with American Legion Highway at the new shopping center. The American Legion Highway would be relocated so that it would be parallel to and on either side of the expressway to a point just south of Morton Street. This location would then proceed northwest through Franklin Park, and then northward to pass between White Stadium and Walnut Avenue. From this point, Location D would pass diagonally through the residential section between Walnut Avenue and Washington Street until it became common again with the Alternate Location along Washington Street north of Columbus Avenue.

Extensive study and analysis were given this alternative, since it results in the most economical location from Cummins Highway northward to an interchange with the Inner Belt. However, economy is not the sole criterion for selection of the route of an expressway, and this location was considered unacceptable and was discarded because it:

a. Passes through the middle of the residential area between Calvary Cemetery and the American Legion Highway, resulting in isolated clusters of residences.
b. Passes immediately adjacent to the Roslindale General Hospital.
c. Seriously impairs the new shopping center on American Legion Highway, requiring the taking of buildings recently constructed, and materially reducing the capacity of the shopping-center parking lot.
d. Requires the relocation of a number of graves in the

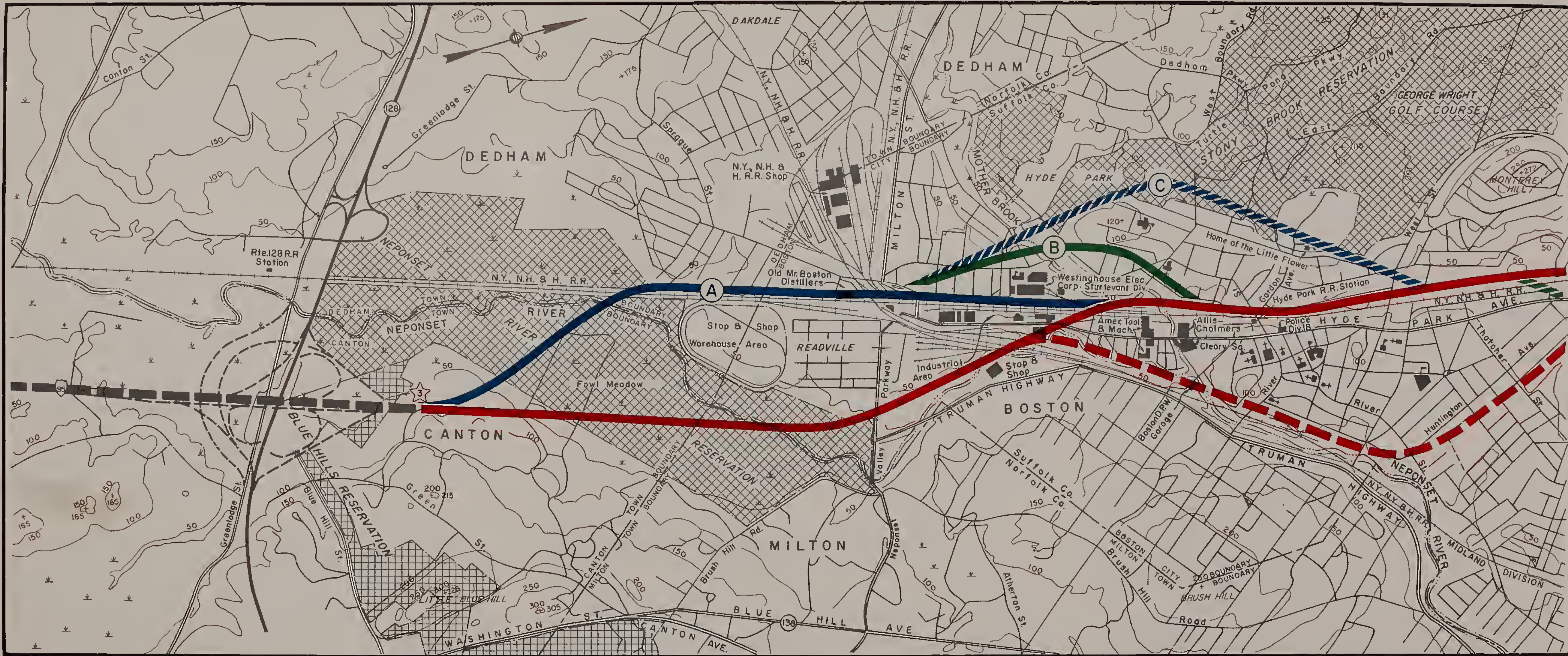


Exhibit B-2

SOUTHWEST EXPRESSWAY STUDY LINES — SHEET 1

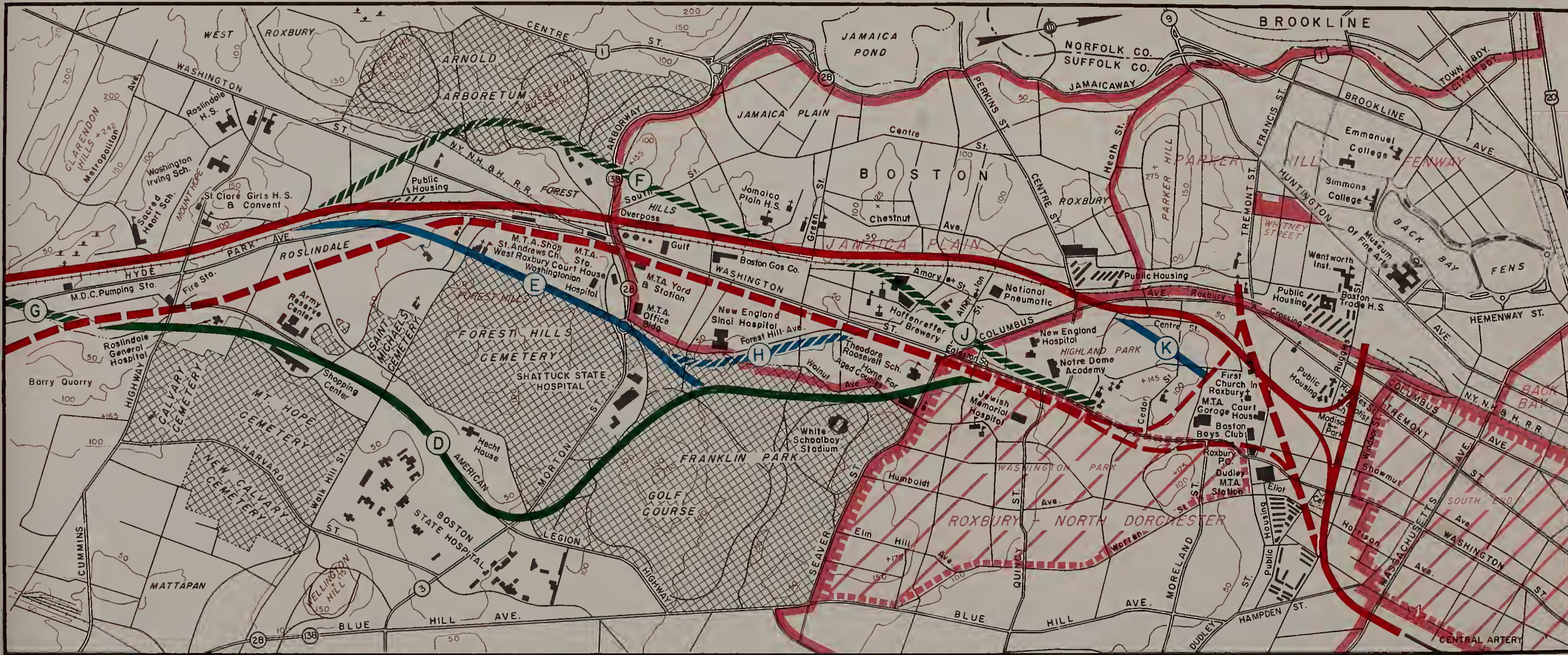


Exhibit B-3

SOUTHWEST EXPRESSWAY STUDY LINES — SHEET 2

LEGEND

- SCHOOLS, CHURCHES
- PUBLIC RESERVATIONS, PARKS CEMETERIES, COUNTRY CLUBS
- RAILROADS & TRANSIT LINES
- CITY OR TOWN BOUNDARY LINES
- URBAN RENEWAL AREAS
  - GENERAL NEIGHBORHOOD RENEWAL PLAN
  - PROJECT IN ADVANCE PLANNING
  - PROJECT IN EXECUTION
- 2 1 93 STATE, U.S., INTERSTATE ROUTES
- TERMINAL CONTROL POINT
- EXISTING EXPRESSWAYS
- OTHER PROPOSED EXPRESSWAYS
- RECOMMENDED LOCATION
- ALTERNATE LOCATION
- ALTERNATIVE LOCATIONS STUDIED

1000 0 1000 2000 3000 FEET

SCALE

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL

easterly corner of Forest Hills Cemetery, as a result of interchanging with Morton Street.

e. Requires the relocation of a part of the municipal golf course on the westerly side of Franklin Park.

f. Isolates small areas of residential property as it approaches Washington Street, and splits land-use patterns.

g. Requires extensive revisions and additions to the existing street system between Morton Street and Columbus Avenue in order to provide adequate traffic service.

ALTERNATIVE LOCATION E

Location E leaves the Recommended Location just south of the Forest Hills MTA Station and passes through the westerly edge of the Forest Hills Cemetery, through a section which contains maintenance sheds and greenhouses. It then proceeds across the traffic circle at the east end of the Forest Hills overpass and becomes common with the northerly end of Location D through Franklin Park. This location requires a 1500-foot length of 4% grade in order to pass over the Forest Hills. It is immediately adjacent to St. Andrew's Church on Walk Hill Street, and would seriously affect the Forest Hills Cemetery; furthermore, frontage roads are precluded for a two-mile length of this location, thereby reducing the effectiveness of the facility in realizing its full potential. Location E was considered unacceptable.

ALTERNATIVE LOCATION F

Location F leaves the Recommended Location south of the Forest Hills MTA Station, passes through the Arnold Arboretum, and rejoins the Recommended Location north of the Forest Hills overpass. Location F was developed with a partial cloverleaf-type interchange at the Arborway, so as to provide full service to and from downtown Boston; however, traffic service to and from the south could not be provided economically. This location passes through a section of Arnold Arboretum and through two residential sections which contain many homes. The resulting separation of these residential areas is such as to render the areas subject to deterioration, due to the influence of the adjacent business section with which this location groups them.

Location F does not improve the local traffic condition at Forest Hills, and adversely affects the general area. The partial ramp service seriously curtails traffic service to the area and reduces the effectiveness and the potential of the MTA rapid transit facilities. Location F was considered unacceptable and was discarded.

● ● ● ● ● ●

Locations G, H, J, and K, as shown on Exhibit B-3, were developed to provide connections between sections of the previously mentioned alternatives and parts of the Recommended or Alternate Location, and these locations were considered unacceptable due to the disadvantages of the alternatives with which each connects.

ANALYSIS OF RECOMMENDED AND ALTERNATE LOCATIONS

TRAFFIC SERVICE

The Recommended Location of the Southwest Expressway provides five local-service interchanges at the following major streets and thoroughfares:

a. Neponset Valley Parkway
b. West Street
c. Cummins Highway
d. Arborway — Morton Street
e. Columbus Avenue — Centre Street

The areas served by these interchanges include Readville, Hyde Park, sections of East Dedham and Milton, Clarendon Hills, Mattapan, Roslindale, West Roxbury, Mt. Hope, Jamaica Plain, Forest Hills, Franklin Park, Roxbury and sections of Dorchester. The interchanges permit all eight turning movements at each location either by semi-direct, loop or parallel-type ramps. Extensive revisions to the local street pattern, as shown on the Basic Design Exhibits, are incorporated at the Cummins Highway, Arborway and Columbus Avenue interchanges to serve the assigned ramp traffic, and to permit the adequate distribution of this traffic to the major arterials. Continuous collector-distributor roadways are provided from the Arborway interchange to the Inner Belt, to augment the existing street system in the collection and distribution of traffic to and from the ramps of the Expressway.

The Alternate Location provides comparable local service to the same major streets listed for the Recommended Locations, as shown on the Basic Design Exhibits. The Neponset Valley Parkway interchange is identical for both the Recommended and Alternate Locations. The remaining four interchanges provide complete turning movements for the major streets by either semi-direct, loop or parallel-type ramps. Extensive revisions to the local street system are required at all four interchange locations, to facilitate ramp traffic collection and distribution to the major streets, and to provide adequate connections to the local street pattern. Continuous collector-distributor roadways are provided from Forest Hills to the Inner Belt collector-distributor system. The Alternate Location north of Forest Hills provides for possible relocation of rapid transit within the Expressway median to replace the present elevated transit service on Washington Street.

PHYSICAL AND FUNCTIONAL EFFECTS

A comparison of the physical effects of the Recommended and Alternate Locations for the Southwest Expressway reveals that they are similar as far as numerical effect is concerned. However, the Recommended Location has decided advantages over the Alternate Location in relation to integration of the Southwest Expressway with present and future land use and effective mass transit for the area.

The Recommended Location parallels the New York, New Haven & Hartford Railroad for practically the entire distance from Route 128 to the Inner Belt, and would cause a minimum of disturbance of the land-use pattern of the area. The Alternate Location requires a separate path for its entire length and therefore tends to split similar land-use patterns. Between Forest Hills and Dudley Street, the Alternate Location results in isolation of a relatively small area between rail and highway facilities, and this will seriously restrict redevelopment of this area.

Both the Recommended and Alternate Locations consider integration of rapid transit facilities with the Expressway. The Alternate Location, between Forest Hills and Dudley Street, assumes that the present MTA elevated tracks would be demolished and the tracks relocated in the median of the depressed Expressway;

the MTA station at Forest Hills would be replaced. Sufficient right-of-way is included to allow a 50-foot reservation in the median for the rapid transit tracks and stations, although no allowance is included in the construction cost for rapid transit facilities.

It would be possible to utilize the main-line tracks of the New York, New Haven & Hartford Railroad to Route 128 Station for rapid transit, with a line to Dedham on the Dover Branch. The Midland Division of the New York, New Haven & Hartford Railroad could be utilized for freight service into the South Station yards. If this, or a similar plan for rapid transit which utilized the railroad right-of-way, could be effected at the time of construction of the Southwest Expressway, the three media of transportation could then be combined in one right-of-way. The Recommended Location would then provide maximum flexibility in redevelopment of the area between Forest Hills and Roxbury Crossing, since one combined transportation artery would traverse the area, instead of two separate arteries.

The interchange of the Recommended Location with the Inner Belt is approximately one-half mile closer to downtown Boston, thereby permitting the Expressway to serve more efficiently its function of providing traffic service for the downtown area. While this factor places the Inner Belt in a more favorable location from a traffic service standpoint, it results in a greater length for the Southwest Expressway, a factor which tends to increase the physical effects associated with the Recommended Location as compared with those of the Alternate Location. The physical effects associated with the Inner Belt, however, strongly favor the Recommended Location over the Alternate Location, and must be considered in the over-all analysis of the choice of the most advantageous location of the interchange.

The Recommended Location involves the taking of approximately 100 fewer residential structures than does the Alternate Location, even though its connection to the Recommended Location of the Inner Belt makes it longer. The total cost of the right-of-way taking is less for the Recommended Location than for the Alternate Location. The assessed valuation of all property taken by the Recommended Location is $8,409,000, and by the Alternate Location, $10,018,000. However, the Alternate Location involves the taking of $2,200,000 more tax-exempt property than does the Recommended Location. Therefore, the Recommended Location results in a $63,000 greater annual tax loss to the City of Boston than the Alternate Location.

TABLE B-V
SOUTHWEST EXPRESSWAY
SUMMARY OF PHYSICAL EFFECTS

NUMBER IN CATEGORY

CITY OR TOWN:	Recommended Location				Alternate Location			
CATEGORY	Canton	Milton	Boston	Totals	Canton	Milton	Boston	Totals
Use of Structures								
Residential	—	—	823	823	—	—	925	925
Retail	—	—	95	95	—	—	84	84
Wholesale	—	—	1	1	—	—	1	1
Business	—	—	12	12	—	—	9	9
Service	—	—	54	54	—	—	55	55
Institutions	—	—	3	3	—	—	4	4
Industry	—	—	47	47	—	—	21	21
Recreation	1	1	7	9	1	1	7	9
Other Data								
Vacant Lots	1	—	291	292	1	—	297	298
Households Displaced	—	—	2,106	2,106	—	—	2,168	2,168
Employees Displaced	—	—	1,178	1,178	—	—	940	940
Tax Loss*	$16,925	Public Lands	$716,352	$733,277	$16,925	Public Lands	$653,196	$670,121

*Based on 1961 tax rates.

Most of the tax-exempt property taken by the Alternate Location involves MTA facilities at Forest Hills, which are valued at almost $2,000,000 and would have to be replaced. The Alternate Location also requires the taking of two public schools. The balance of the tax-exempt property taken by the Alternate Location, and the bulk of the tax-exempt property taken by the Recommended Location, are the M.D.C. lands of the Neponset River Reservation, which is predominantly marsh land.

Listed in Table B-V are the various categories of property which are affected by the respective expressway locations. As noted, the number of retail, wholesale, business, service and institutional establishments affected by each location is generally the same. Although the number of industries affected by the Recommended Location is twice as great as that affected by the Alternate Location, the number of employees displaced is only slightly greater, since many of the industries affected by the Recommended Location employ only a few employees each. Approximately 40% of all land which would be taken for either location is vacant.

The Recommended Location, for the most part, takes marginal property which presently abuts the railroad right-of-way. In the area between Readville and Roxbury Crossing it acts as a buffer between the residential section and the railroad. The Alternate Location disrupts the residential community off River Street, another between Hyde Park Avenue and American Legion Highway, and the business section at Forest Hills.

These physical effects on the economy of Boston are short-term. The functional effect of the Southwest Expressway will be such as to provide vastly improved accessibility to the Jamaica Plain, Roslindale, and Hyde Park sections of Boston. This greater

TABLE B-VI
SOUTHWEST EXPRESSWAY
PROJECT COSTS

In Thousands of Dollars

RECOMMENDED LOCATION

Section Number	Construction Costs: Structures	Earthwork	Pavement	Utility Relocation	Miscel-laneous	Total Construction Cost	Demolition Cost	Construction Cost Plus Demolition	Engineering and Contingencies	Right-of-Way Costs, Total Fair Market Value	Total Costs
1	$ 2,586	$ 554	$ 275	$ 189	$ 189	$ 3,793	$ 273	$ 4,066	$ 610	$ 1,592	$ 6,268
2	7,711	1,128	806	454	517	10,616	329	10,945	1,642	4,414	17,001
3	9,580	833	563	197	597	11,770	159	11,929	1,789	3,781	17,499
4	6,197	933	1,062	305	734	9,231	170	9,401	1,410	4,509	15,320
5	1,173	1,355	406	64	266	3,264	13	3,277	492	782	4,551
6	346	1,291	451	—	290	2,378	—	2,378	357	1,014	3,749
Totals	$ 27,593	$6,094	$3,563	$1,209	$2,593	$ 41,052	$ 944	$ 41,996	$ 6,300	$16,092	$ 64,388

ALTERNATE LOCATION

Section Number	Structures	Earthwork	Pavement	Utility Relocation	Miscel-laneous	Total Construction Cost	Demolition Cost	Construction Cost Plus Demolition	Engineering and Contingencies	Right-of-Way Costs, Total Fair Market Value	Total Costs
1	$ 940	$1,454	$ 365	$ 154	$ 201	$ 3,114	$ 212	$ 3,326	$ 499	$ 2,121	$ 5,946
2	5,499	2,683	667	313	510	9,672	248	9,920	1,488	3,799	15,207
3	4,646	2,892	709	215	491	8,953	290	9,243	1,386	5,886	16,515
4	3,386	2,240	1,019	355	780	7,780	157	7,937	1,191	3,270	12,398
5	1,173	1,355	406	64	266	3,264	13	3,277	492	782	4,551
6	346	1,291	451	—	290	2,378	—	2,378	357	1,014	3,749
Totals	$ 15,990	$11,915	$3,617	$ 1,101	$2,538	$ 35,161	$ 920	$ 36,081	$ 5,413	$16,872	$ 58,366

COST SECTIONS

1. Linden Park Street to Columbus Avenue — Recommended Location
   Kingsbury Street to Columbus Avenue — Alternate Location
2. Columbus Avenue to Arborway-Morton Street
3. Arborway-Morton Street to Cummins Highway
4. Cummins Highway to New York, New Haven & Hartford Railroad
5. New York, New Haven & Hartford Railroad to Town Lines (Boston-Milton)
6. Town Lines (Boston-Milton) to Route 128

PROJECT COSTS PER MILE

	Recommended	Alternate
Number of Miles	8.7	8.4
Construction and Engineering Cost/Mile	$5,551	$4,940
Right-of-Way Cost/Mile	$1,850	$2,008
Project Cost/Mile	$7,401	$6,948

accessibility will result in increased property values as new industries take advantage of the proximity to the downtown Boston area. The area east of the railroad between Roxbury Crossing and Forest Hills is predominantly industrial in character at present, and the resulting improvement in accessibility will provide the impetus for its expansion. The area south of Forest Hills will become readily accessible to all parts of Metropolitan Boston by virtue of the Expressway, and its desirability as a residential neighborhood will increase together with property values. The net effect of the Expressway several years after completion will be to increase the tax base of Boston sufficiently to offset the initial loss resulting from the displaced properties.

COST ANALYSIS

The summary of costs of the Recommended and Alternate Locations of the Southwest Expressway is presented in Table B-VI. Supplementing the description given in Part II of the general factors affecting costs, the following features influence the construction costs of the Southwest Expressway.

The cost of the foundations for the structures of the Southwest Expressway are based on the use of piles in the area between Route 128 and Forest Hills, and spread footings in the area north of Forest Hills. The construction cost of the Expressway through the Neponset River Reservation is based on removal of the peat and replacement with granular material. The Recommended Location requires 9,000 feet of viaduct as opposed to 3,000 feet of viaduct required for the Alternate Location. The Recommended Location requires the relocation of 2,300 feet of the New York, New Haven & Hartford Railroad south of Forest Hills. The Alternate Location requires the relocation of 2,000 feet of the Neponset River, and also requires the extensive use of retaining walls for the depressed roadway between Forest Hills and Kingsbury Street. Both Locations require extensive local street improvements at Forest Hills in order to provide adequate facilities for local service to the Expressway.

ROAD-USER BENEFIT ANALYSIS

The results of the road-user benefit analyses described in Part II and applied to the Recommended and Alternate Locations of the Southwest Expressway are shown in Table B-VII. The annual road-user benefit values more than justify the construction of either location as economically sound. The values show an economic advantage in favor of the Recommended Location of approximately $1.1 million annually, primarily because the Recommended Location is a more direct route than the Alternate Location. The road-user benefit ratio, which compares travel on the new facility to existing street travel, indicates a 4.3-to-one economic advantage by the use of the expressway as compared with existing streets.

SUMMARY

Interstate Route 95 is one of the major highways of the Interstate System connecting the major urban areas along the Atlantic seaboard. Two sections in Massachusetts are completed: the Central Artery-Northeast Expressway from Massachusetts Avenue, Boston, to Cutler Circle in Revere, and from Danvers to the New Hampshire State Line. I-95 is under construction or in various stages of design from the Rhode Island State Line to Route 128. The Southwest Expressway forms that part of Interstate Route 95

TABLE B-VII
SOUTHWEST EXPRESSWAY
ROAD-USER BENEFIT ANALYSIS

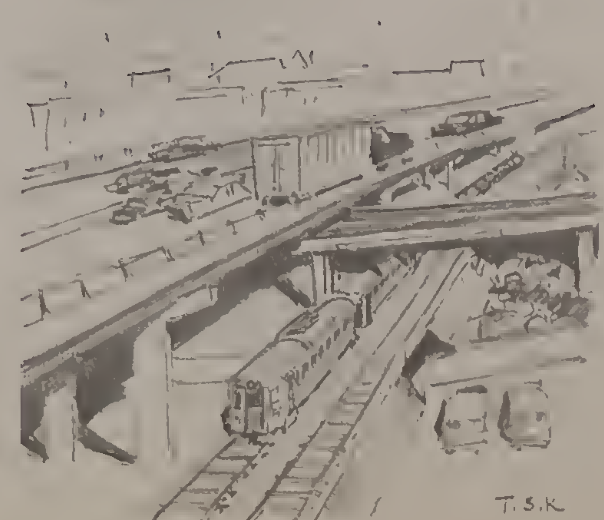
Item	Recommended Location	Alternate Location
Length, miles	8.7	8.4
Annual Road-User Benefit	$14,290,000	$13,227,000
Annual Cost of Expressway	$ 3,308,000	$ 3,233,000
Road-User Benefit Ratio	4.3	4.1

from Route 128 northward to the Inner Belt, which connects with the southerly terminus of the completed segment of I-95 in Boston. In addition to being a part of one of the major interstate highways, the Southwest Expressway, as one of the radials of the Expressway System, serves the entire southwest quadrant of the Boston Metropolitan Area. The existing system of arterial streets and thoroughfares in this quadrant of the Metropolitan Area is grossly inadequate to satisfy the demands of even present day use; it is heavily congested and does not provide a direct route into downtown Boston. Lack of accessibility for this area is evidenced by the fact that the southwest quadrant of Boston has received far less than its proportionate share of new development, and that a large volume of traffic with origins in the Canton, Dedham, Norwood and Westwood area is presently using the Southeast Expressway for travel to downtown Boston.

Construction of the Southwest Expressway in the Recommended Location will:

a. Provide the most direct route from Route 128 to the Inner Belt, provide the highest degree of traffic service for the Jamaica Plain, Roslindale and Hyde Park sections of Boston, provide efficient service to those areas on both sides of the New York, New Haven and Hartford Railroad tracks, and the collector-distributor roadway provides an even distribution of traffic to the existing street system.
b. Afford far greater opportunity for integration of the several modes of transportation in one corridor, and concurrently provide the greatest potential for future redevelopment of the area.
c. Result in displacement of fewer residential structures and households, and lower cost of right-of-way acquisition than the Alternate Location. In consideration of the advantage of the location of the interchange with the Inner Belt, one-half mile closer to downtown Boston, the sum of the physical effects favor the Recommended Location.
d. Provide over $1 million greater direct annual benefit to the road users than will the Alternate Location.

The completion of Interstate Route 95 in its entirety is vital to the economy and defense capability of the entire New England Area, since it serves as the major highway transportation artery for the eastern seaboard. The Southwest Expressway, being an integral part of this major highway, will be a prime factor in commercial, industrial and residential development of the southwest sector of Boston and adjacent communities. With the through-traffic diverted from the existing arterial street system, the substantially increased accessibility to all parts of New England will enable the southwest sector to realize its economic potential and to assume its rightful share in the future growth of the Boston Metropolitan Area.



SECTION 3 — THE ROUTE 3 EXPRESSWAY

GENERAL

Route 3, one of the major north-south routes of the Federal-Aid Primary Highway System, has been essentially completed from the New Hampshire State Line to Route 128 in Burlington. To complete this facility, an extension must be made southerly from Route 128 to integrate with the Expressway System. The Route 3 Expressway will then become a major traffic distributor for the northwest sector of the Boston Metropolitan Area. In order to provide optimum traffic service in this sector, the expressway must be located so that it will relieve the local street systems in Arlington, Belmont, Lexington, Winchester, and Woburn, of heavy commercial and commuting traffic.

The northerly control point for this Expressway, shown as Terminal Control Point 5 on Exhibit L-1, is established by the existing cloverleaf interchange with Route 128 in Burlington. This is one of the seven terminal control points outlined in Part II. The locations of the southerly control points have been determined, as a result of this Study, to be either a connection to the Northwest Expressway, in the vicinity of Alewife Brook Parkway in North Cambridge, or a connection to both the Northern Expressway at Main Street, Medford, and the Northwest Expressway.

TOPOGRAPHY AND SUBSURFACE CONDITIONS

Some of the major topographic controls which influence the locations of the Route 3 Expressway are the Great Meadows, the Mystic Lakes, the Arlington Reservoir, and Spy Pond. The wide corridor for the location studies of Route 3 passes through three geologically separate areas as described herein. Topographic maps of the area northwest of Boston show a ridge to the west of Belmont Center that extends northeasterly, past the northwest side of Spy Pond, approximately to Arlington Center, then northerly, passing around the Mystic Lakes, and then easterly, parallel to the Mystic Valley Parkway. This ridge is the northwesterly rim of the Boston Basin, at which the subsurface soil conditions change markedly from the typical Boston Basin deposits to the frequent bedrock outcropping and irregular glacial till formations of the uplands. The mantle of till over the bedrock varies up to ten feet in thickness. Within the valley in this area, the depth of the till deposit increases, and is often overlain with sands and silts of alluvial and fluvio-glacial origin. Construction in this area may require considerable rock excavation.

In the lowlands below this ridge, south of the Alewife Brook Parkway, the Expressway follows approximately within the Mystic River flood plain. Except for the alluvial sands of the flood plain, the soils consist of the typical deposits of the Boston Basin, usually overlain by granular soils and fill. The clay becomes increasingly deep toward Alewife Brook Parkway, reaching a depth of 50 to 100 feet in the vicinity of the intersection of existing Route 2 and the Parkway, but is somewhat shallower, 30 to 60 feet, at the northerly end of the Parkway. The section of Alewife Brook Parkway from existing Route 2 to the intersection with the Mystic Valley Parkway lies entirely within the Boston Basin. In the vicinity of Route 2 and Alewife Brook Parkway considerable filled land is also present, trapping pockets of soft peats and organic silts beneath the fill material. The depth to bedrock in this area is quite erratic, but is expected to be over 100 feet. Near the rim of the Basin, the clay is also shallow but appears to be more sandy, and the desiccated upper clay crust is thicker.

North of the ridge, all locations converging on the existing interchange at Route 128 traverse a relatively flat area. The subsurface deposits in this area consist of a mixture of randomly deposited granular soils overlying the relatively impermeable till. In this area the water table is relatively high, resulting in a surface condition of localized marshes and swamps. The lower areas, Lexington's Great Meadows, for example, have accumulated a surface layer of peat which is seldom more than a few feet thick.

LOCATIONS STUDIED

The several locations for Route 3 which were studied, before a selection of the Recommended and Alternate Locations was made, are shown on Exhibits B-4 and B-5 and are referred to hereinafter as follows:

Recommended Location: Great Meadows—Route 2 location.
Alternate Location: Hutchinson Road—Mystic Valley—Alewife Brook Parkway location.
Alternative Location A: Morningside location.
Alternative Location B: Cambridge Street—Mystic Lakes location.
Alternative Location C: Railroad location.
Alternative Location D: Belmont location.
Alternative Location E: Mystic Lakes—Railroad location.
Alternative Location F: East Arlington location.
Alternative Location G: Summer Street location.

DESCRIPTION OF RECOMMENDED AND ALTERNATE LOCATIONS

The Recommended Location extends southerly from the existing interchange with Route 128, shown as Terminal Control Point 5, and passes through the Great Meadows in Lexington, to existing Route 2 at a point near the Arlington-Lexington Town Line. It then extends along existing Route 2 to the Recommended Location of the Northwest Expressway in the vicinity of Alewife Brook Parkway in North Cambridge.

The Alternate Location extends southeasterly from the existing interchange at Route 128 parallel to the Lexington Town Line, and passes between the Upper and Lower Mystic Lakes to the Mystic River. It then follows the Mystic River Valley to Alewife Brook Parkway, where it interchanges with a connector located along Alewife Brook and Mystic Valley Parkways between the Northwest Expressway, in North Cambridge, and the Northern Expressway, in Medford.

Reference should be made to the Basic Design Exhibits for the Recommended and Alternate Locations.

DESCRIPTION AND ANALYSIS OF OTHER LOCATIONS STUDIED

In addition to the Recommended and Alternate Locations, other alternative locations that were studied and determined to be less advantageous are described below.

ALTERNATIVE LOCATION A

This location begins at the existing interchange on Route 128, and is common to the Alternate Location to Johnson Road, Winchester. From Johnson Road, Location A extends southerly, passing

through the Morningside section of Arlington and across the southern end of the Lower Mystic Lake to the Mystic River Valley, where it again becomes common to the Alternate Location.

When the Morningside location was first considered, there existed an open corridor in which an expressway could be constructed. Since that time, however, high-value residential construction has proceeded at a very rapid pace, effectively blocking this corridor. Within the past year at least 200 residences have been constructed in this area. While Alternative Location A has steep gradients similar to the other alternatives, a crossing of the southerly end of the Lower Mystic Lake would be more costly and difficult than a crossing between the lakes, as in the Alternate Location, because of the depth of the lake at the mouth of the Mystic River. This alternative offers no advantages over the Alternate Location, and has the disadvantage of passing through a highly developed, attractive and rapidly expanding residential neighborhood. This location was therefore considered unacceptable and thus was discarded.

ALTERNATIVE LOCATION B

Alternative Location B extends southeasterly from the existing interchange at Route 128 to the Woburn-Winchester Town Line near existing Route 3. From this point it extends southerly and parallel to existing Route 3, crosses the Upper Mystic Lake, and follows the Mystic Valley Parkway to the Mystic River Valley, where it becomes common to the Alternate Location.

Since this location is more easterly than all other locations considered, it provides the least service to the Arlington and Lexington areas, the major traffic generators in this sector. Several other disadvantages of this location include the passage through extensive residential areas, and considerable reduction of the recreational value of the Mystic Lakes, particularly the complete disruption of the Metropolitan District Commission Beach Reservation. As with Alternative Location A, this location offers no material advantages over the Alternate Location and provides only limited traffic service for the major traffic generating areas. This location was also considered unacceptable and therefore was discarded.

ALTERNATIVE LOCATION C

Location C is common to the Recommended Location southerly from Route 128 to the Boston & Maine Railroad in East Lexington. It then extends along the railroad through Arlington Center to existing Route 2 in the vicinity of Alewife Brook Parkway in North Cambridge.

Although construction of this alternative would improve conditions on some of the local streets in Arlington, through elimination of railroad grade-crossings and improved grade separations, it was discarded because its construction would require complete abandonment of the railroad. The inadequacy of the existing street network to provide local traffic service, and the physical effect on a recently-constructed Old Age Housing Project, as well as several athletic fields, parks, and industries adjacent to the railroad, are other disadvantages of this alternative. Furthermore, the converging of Alewife Brook Parkway, Route 2, the Northwest Expressway and Route 3 in the same general area precludes the construction of an interchange which would provide adequate service for all of these roadways.

ALTERNATIVE LOCATION D

This Alternative is also common to the Recommended Location from the Route 128 interchange to the Concord Turnpike. From this point it continues over the Turnpike and Concord Avenue, turns southeasterly parallel to Concord Avenue, passes to the north of the McLean Hospital, crosses over Belmont Hill, crosses Pleasant Street (Route 60), and the Boston & Maine Railroad, and then follows the railroad to Alewife Brook Parkway in North Cambridge.

In addition to the disadvantage of long, steep gradients required to cross Belmont Hill, this location is much longer than other alternatives, creates serious interchanging problems, disrupts business and traffic movements in Belmont Center, passes through the Belmont Country Club and the High School Athletic Field, and displaces several commercial establishments adjacent to the railroad in Belmont and in Cambridge. For these reasons, this alternative was considered unacceptable and therefore was also discarded.

ALTERNATIVE LOCATION E

Location E is common to the Alternate Location to a point between the Upper and Lower Mystic Lakes. From this point it continues across the lakes and extends along the Boston & Maine Railroad to the Mystic River, where it interchanges with a connector between the Northwest Expressway and the Northern Expressway. As compared to other locations along the Mystic River Valley, this location affects more residential, commercial and industrial establishments in West Medford and along Mystic Valley Parkway. This location was therefore considered unacceptable and was discarded in favor of those locations along the Mystic River Valley.

ALTERNATIVE LOCATION F

This location is common to the Alternate Location as far as Medford Street in Arlington. From Medford Street, this alternative extends through the Thompson Elementary School Playground, over Broadway, to the west of St. Paul's Cemetery, and along Alewife Brook Parkway to the Northwest Expressway in North Cambridge. This alternative was also considered unacceptable and therefore was discarded, because it has no advantage over those locations along the Mystic River Valley, and it causes excessive land damages in East Arlington, affects the Thompson Elementary School, and isolates a section of East Arlington.

ALTERNATIVE LOCATION G

This location is common to the Recommended Location as far as Woburn Street in Lexington. From Woburn Street it extends over Maple Street, through the northern portion of the Great Meadows, over Lowell Street and then parallels Summer Street until it becomes common to Alternative Location C at the Summer Street Playground. As with Alternative Location C, previously discarded, this alternative also requires abandonment of the railroad. Because this location presents this disadvantage as well as the same additional disadvantages as Alternative Location C, it was considered unacceptable and was discarded.

Exhibit B-4

 ROUTE 3 AND NORTHWEST EXPRESSWAY STUDY LINES — SHEET 1

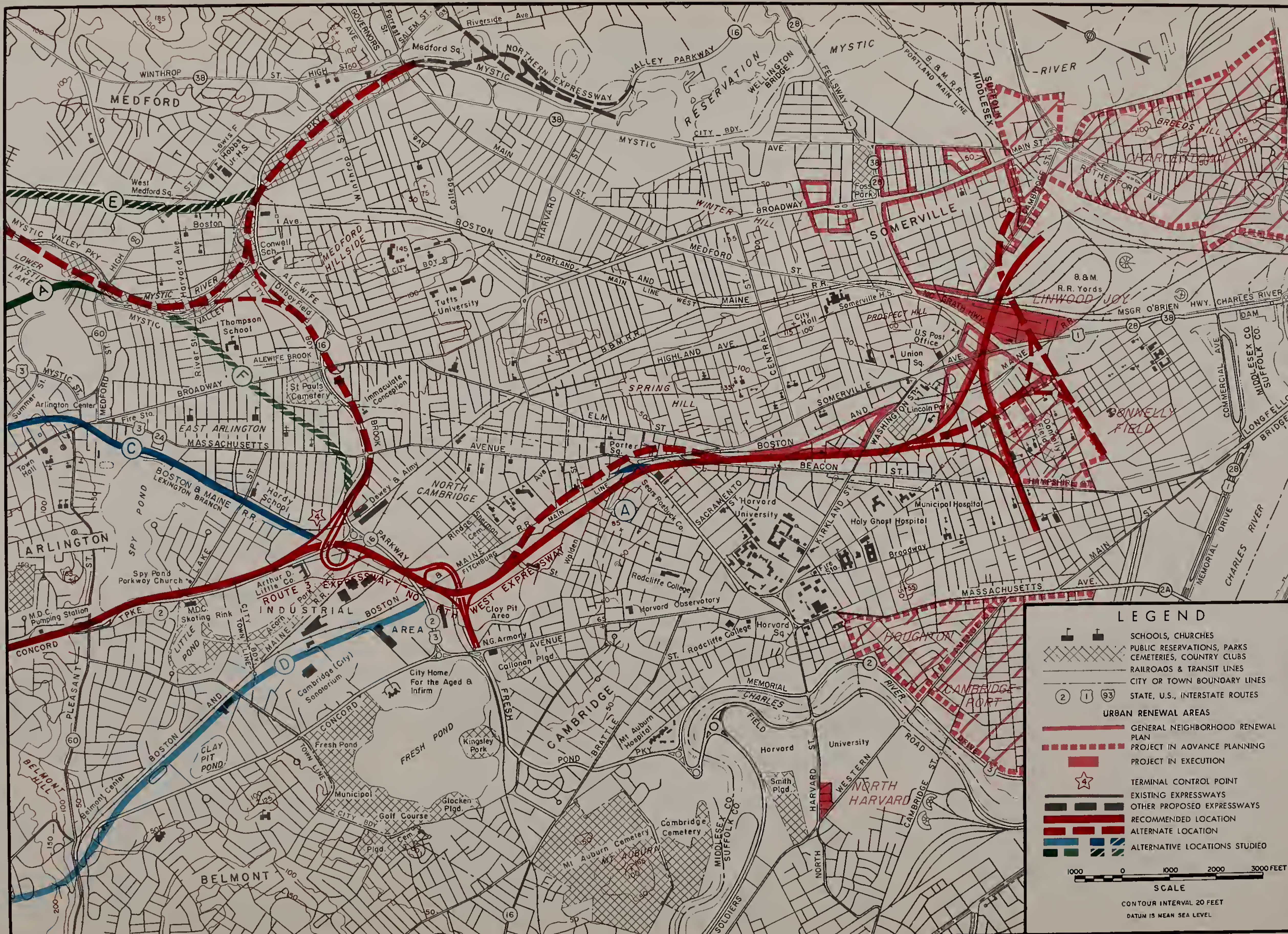


Exhibit B-5

ROUTE 3 AND NORTHWEST EXPRESSWAY STUDY LINES — SHEET 2

TABLE B-VIII
ROUTE 3 EXPRESSWAY
SUMMARY OF PHYSICAL EFFECTS

	NUMBER IN CATEGORY												
	Recommended Location					Alternate Location							
CITY OR TOWN:	Lexington	Arlington	Belmont	Cambridge		Woburn	Lexington	Winchester	Arlington	Medford	Cambridge	Somerville	
CATEGORY					Totals								Totals
Use of Structures													
Residential	51	90	49	4	194	7	25	13	126	24	4	9	208
Retail	—	—	—	6	6	—	—	—	—	1	4	—	5
Wholesale	—	—	—	—	—	—	—	—	—	—	—	—	—
Business	—	—	—	—	—	—	—	—	2	—	1	—	3
Service	4	—	—	—	4	—	—	—	1	—	—	1	2
Institutions	—	1	—	—	1	—	—	—	—	—	—	—	—
Industry	—	—	—	3	3	—	—	—	—	—	1	—	1
Recreation	1	1	—	—	2	—	—	—	—	2	—	—	2
Other Data													
Vacant Lots	5	5	1	4	15	1	4	3	—	1	—	—	9
Households Displaced	52	90	49	6	197	7	25	13	189	33	8	20	295
Employees Displaced	14	—	—	66	80	—	—	—	8	3	53	30	94
Tax Loss*	$46,960	$47,490	$38,940	$35,400	$168,790	$5,440	$25,230	$20,360	$70,250	$15,820	$26,200	$25,320	$188,620

*Based on 1961 tax rates.

ANALYSIS OF RECOMMENDED AND ALTERNATE LOCATIONS

TRAFFIC SERVICE

The Recommended Location of the Route 3 Expressway, from Route 128 to the Northwest Expressway at Alewife Brook Parkway, provides traffic service for Burlington, Woburn, Lexington, Arlington, Belmont and Cambridge. From Route 128 to its junction with Route 2, approximately one-half of the assigned traffic originates in areas served by Route 3 outside of Route 128. Two local-service interchanges are provided between Route 128 and Route 2, one at Woburn Street and one at Massachusetts Avenue, both in Lexington. Each of these are diamond-type interchanges, providing complete traffic service. The local-service interchanges are designed to accommodate the assigned traffic and, where necessary, may be signalized. At the junction with Route 2, a Y-type direct-connector interchange is provided. Between this interchange and Alewife Brook Parkway, a total of eight parallel ramps, which act as split-diamond interchanges, are provided for local traffic service. These ramps serve traffic from the Arlington and Belmont Areas. At Alewife Brook Parkway, a full-service trumpet-type interchange is provided between the Parkway and Route 3. Local traffic service between the Route 3 frontage roads and Alewife Brook Parkway has also been provided. The frontage road system provided from Watertown Street, Lexington, to Alewife Brook Parkway will serve effectively to restore existing local service, as well as to augment the capacity of Route 3.

In the Alternate Location, Route 3 provides traffic service for Burlington, Woburn, Winchester, Lexington, Arlington, Medford, and Somerville. Between Route 128 and Alewife Brook Parkway, local service is provided at Woburn Street, Lexington, at Ridge Street, Winchester, at Mystic Street, Arlington, and at High Street, Medford. With the exception of the interchange at Mystic Street, where a modified diamond interchange is provided because of topographic considerations, these are proposed as full diamond interchanges.

The interchange of the Alternate Location of Route 3 with the connector between the Northwest and Northern Expressways is a fully-direct Y-type interchange. This connector extends from the Northwest Expressway, along Alewife Brook to its confluence with the Mystic River, and along the Mystic River to the Northern Expressway, which is now under construction. The interchange between this connector and Route 2 is also a fully-direct Y-type interchange. Local-service connections between Alewife Brook Parkway and the frontage roads on Route 2 are provided. Alewife Brook Parkway, from Route 2 northerly to the Route 3 interchange, is designed to serve as a frontage road on each side of the proposed expressway. The existing Mystic Valley Parkway, from the Route 3 interchange easterly to the Northern Expressway, serves as a two-way frontage road. Local service is provided by four parallel ramps to the frontage roads.

TABLE B-IX
ROUTE 3 EXPRESSWAY
PROJECT COSTS

In Thousands of Dollars

Section Number	Construction Costs: Structures	Earthwork	Pavement	Utility Relocation	Miscellaneous	Total Construction Cost	Demolition Cost	Construction Cost Plus Demolition	Engineering and Contingencies	Right-of-Way Costs, Total Fair Market Value	Total Costs
RECOMMENDED LOCATION											
1	$ 1,722	$1,812	$1,021	$ 50	$ 829	$ 5,434	$ 94	$ 5,528	$ 830	$ 1,608	$ 7,966
2	4,093	1,714	1,590	1,055	977	9,429	272	9,701	1,455	3,634	14,790
3	6,415	1,154	319	80	310	8,278	40	8,318	1,248	792	10,358
Totals	$ 12,230	$4,680	$2,930	$1,185	$2,116	$ 23,141	$ 406	$ 23,547	$ 3,533	$ 6,034	$ 33,114
ALTERNATE LOCATION											
4	$ 3,240	$3,851	$1,585	$ 70	$1,277	$ 10,023	$ 129	$ 10,152	$ 1,522	$ 2,732	$ 14,406
5	20,726	2,367	1,110	840	1,169	26,212	334	26,546	3,982	3,345	33,873
Totals	$ 23,966	$6,218	$2,695	$ 910	$2,446	$ 36,235	$ 463	$ 36,698	$ 5,504	$ 6,077	$ 48,279

COST SECTIONS

1. Route 128 to Route 2
2. Route 2 to Alewife Brook Parkway
3. Alewife Brook Parkway to Northwest Expressway
4. Route 128 to Alewife Brook Parkway
5. Northwest-Northern Connector

PROJECT COSTS PER MILE

	Recommended	Alternate
Number of Miles	7.7	9.2
Construction and Engineering Cost/Mile	$3,517	$4,587
Right-of-Way Cost/Mile	$ 784	$ 661
Project Cost/Mile	$4,301	$5,248

Traffic assigned to the interchange of the Northern Expressway with the Mystic Valley Parkway, presently under construction, indicates the desirability of a ramp from the southbound lane of the Northern Expressway to the westbound Mystic Valley Parkway. However, the ramps presently under construction at Salem Street and Main Street are of equal importance for the local traffic movements and preclude the provision of such a ramp.

PHYSICAL AND FUNCTIONAL EFFECTS

An evaluation of the physical effects of the Recommended and Alternate Locations of the Route 3 Expressway, shown in Table B-VIII, must take into consideration the proposed widening of existing Route 2 currently being designed by the Department of Public Works. The majority of the effects upon the towns of Arlington and Belmont shown in Table B-VIII will occur as a result of this widening. Evaluating the data on this basis shows that approximately 240 fewer households are affected by the Recommended Location than by the Alternate Location. Also, the annual tax loss to the communities, while only temporary, is at least $100,000 less for the Recommended Location. Thus, by combining the two facilities, the resulting physical effect on the communities involved is far less.

The Recommended Location, through Lexington to Route 2 where the routes combine, passes for the most part through relatively sparsely developed areas, without any appreciable effect on existing municipal service districts. From Route 2 to Alewife Brook Parkway, the Expressway is located on the Arlington-Belmont Town Line, thereby having no effect on existing municipal service districts.

The Alternate Location extends generally along the town lines of Woburn, Winchester, Lexington and Arlington, with minimum effect on the existing municipal service districts in these towns. However, a small section of Winchester is located between the Expressway and the Arlington and Lexington town lines, and a small section of Arlington is located between the Expressway and the Winchester and Medford town lines. These areas are, how-

ever, accessible to the main body of their respective towns via major surface streets which are bridged by the Expressway. In addition to causing greater physical effects when considered together with the widening of Route 2, the Winchester Country Club, the Medford Boat Club and the shore properties along the Mystic Lakes are also seriously affected.

The towns of Arlington, Belmont, Burlington, Lexington, Winchester and Woburn, the major communities serviced by the Route 3 Expressway, will experience a combined population growth of 26,000 and an employment growth of 18,000, between the present and 1975. This population growth will stimulate the demand for new home construction in these communities, and will increase the real value of present residential and commercial properties. These new residential developments will, in turn, create a demand for new business and convenient shopping centers. Increased acccessibility afforded by the Expressway System, and a substantial labor force, will promote the development of additional commercial and industrial activities. Between now and 1975 approximately 4,000 residential and 900 commercial and industrial acres will be developed in these communities in response to the increased accessibility provided by the Expressway System.

As outlined in *Industrial Land Needs Through 1960*, a recent publication of the Greater Boston Economic Study Committee, ". . . Interstate (Route) 93 and Route 3 are likely to play a major role in the region's industrial future. They connect major population and labor concentrations with Route 128, and traverse populous suburbs. . . ." The physical effects noted in Table B-VIII will create temporary short-run effects on the communities through which they pass, and the local governments will be affected by a temporary reduction in taxable properties. However, the communities' tax bases will actually be strengthened as residential property values rise and new businesses and industries locate in these communities.

COST ANALYSIS

The summary of costs of the Recommended and Alternate Locations of the Route 3 Expressway is presented in Table B-IX. A comparison of the costs of constructing the expressways, as shown on the Basic Design Exhibits, indicates an incremental saving of $15 million for the Recommended Location. However, two additional important considerations must be taken into account when evaluating the costs for the Route 3 Expressways. To allow greater dispersion of traffic for the Recommended Location, it is recommended that an expressway be extended along Alewife Brook and Mystic Valley Parkways similar to that shown for the Alternate Location. The cost of providing this facility is estimated to be $13.1 million. The Department of Public Works is currently planning to construct a limited-access facility along existing Route 2. The cost attributable to this facility must be considered while evaluating the Alternate Location. The cost for the limited-access expressway along Route 2 is estimated to be $12.6 million for a six-lane roadway with frontage roads. When Routes 2 and 3 are combined, as recommended, an eight-lane roadway with frontage roads is required.

A comparison of the cost estimates, in consideration of providing an express facility along Route 2 for the Alternate Location, and an express facility along Alewife Brook Parkway for the Recommended Location, is as follows:

Alternate Location	$48.3 million
Route 2 Widening	12.6 million
Total	$60.9 million

Recommended Location	$33.1 million
Northwest-Northern Connector	13.1 million
Total	$46.2 million

Thus, by combining Routes 2 and 3, as recommended, more than $14.5 million will be saved.

No particular foundation problems are anticipated for the construction of the Route 3 Expressway. The costs of the foundations for those structures generally located within the Boston Basin, where the Boston Blue Clay is prevalent, are based upon the use of pile construction. For those structures generally located outside the Basin, where the soil is characterized by frequent rock outcroppings and glacial till, the costs are based upon the use of spread footings. The construction of the expressway along Alewife Brook and the Mystic River Valley requires the relocation of approximately 18,000 feet of Alewife Brook and the Mystic River. The Recommended Location requires 3,500 feet of viaduct construction while the Alternate Location requires 13,000 feet. The Alternate Location also requires the construction of an earth embankment 3,700 feet long through the Mystic Lakes, while the Recommended Location requires an earth embankment 1,700 feet long in Spy Pond. The costs outlined in Table B-IX are based upon these considerations.

TABLE B-X
ROUTE 3 EXPRESSWAY
ROAD-USER BENEFIT ANALYSIS

Item	Recommended Location	Alternate Location
Length, miles *	10.4	12.7
Annual Road-User Benefit	$11,630,000	$12,130,000
Annual Cost of Expressway	$ 2,798,000	$ 3,680,000
Road-User Benefit Ratio	4.2	3.3

*Combined length Route 3, Route 2 and Northwest-Northern Connector.

ROAD-USER BENEFIT ANALYSIS

The results of the road-user benefit analyses for the Recommended and Alternate Locations, shown in Table B-X, take into consideration the complete expressway system in the northwest sector: a Route 3 Expressway, a limited-access facility along Route 2 and a connector between the Northwest and Northern Expressways. The annual road-user benefit values more than justify the construction of either the Recommended or Alternate Locations as economically sound. The road-user benefit ratio, which compares travel on the new facility to existing street travel, results in a 4.2-to-one economic advantage by use of the Recommended Location as compared with the existing street network. The values also show an economic advantage for the Recommended Location over the Alternate Location. While the annual benefits for the Alternate

are $500,000 greater, the annual costs are $880,000 greater, almost twice as much as the savings.

SUMMARY

The Route 3 Expressway, which has been completed as far north as Tyngsborough, near the New Hampshire State Line, presently terminates at Route 128 in Burlington, and consequently does not provide traffic service between Route 128 and the Core Area. The residents of those communities outside of Route 128 must presently travel north or south on Route 128 to either Route 2 or Interstate Route 93, then easterly to the Core Area, or travel on highly congested local streets in Arlington, Lexington, Winchester and Woburn. The traffic generated within these communities must also travel on these limited-capacity surface streets.

The Department of Public Works is currently planning to construct a limited-access highway from Route 128 to Alewife Brook Parkway, along the present location of Route 2. Integration of these plans with the Route 3 Expressway, as recommended herein, will provide efficient traffic service for the northwest sector in the most economical manner and with the least physical effect upon the communities involved. The completion of this facility, and its extension to the Inner Belt will relieve the existing local streets in this sector of heavy through-traffic, thus improving the environment of the residential and commercial areas.

Construction of the Route 3 Expressway in the Recommended Location will:

a. Provide better traffic service for the northwest sector at less total cost, including the improvement of Alewife Brook and Mystic Valley Parkways, than would the Alternate Location.

b. Affect approximately 240 fewer households than the Alternate Location when all expressways in the northwest sector are considered.

c. Result in a minimal effect on the communities through which it passes.

With the completion of the Route 3 and Northwest Expressways, the northwest sector will become readily accessible to all parts of the Metropolitan Area; its attractiveness as a residential area will continue and its desirability as an area for commercial and industrial expansion will be significantly enhanced, with the concomitant effect of an increase in real property value. The stimulated economy and increase in property values will broaden the communities' tax bases and result in the improved over-all economy of the region.

SECTION 4 – THE NORTHWEST EXPRESSWAY

GENERAL

The Northwest Expressway, which extends from Alewife Brook Parkway to the Inner Belt Expressway, is an integral section of Route 2. Route 2, which is one of the major east-west roadways included in the Federal-Aid Primary Highway System, extends to the New York State Line just west of North Adams, Massachusetts. At the present time the Commonwealth is planning to improve several sections of this roadway. The three-mile extension from Alewife Brook Parkway to the Inner Belt Expressway is included in this Study. When completed, Route 2 will be one of the major traffic distributors for this section of the Boston Metropolitan Area.

The westerly control point for this Study, shown as Terminal Control Point 4 on Exhibit L-1, was established by previous engineering studies as the vicinity of the intersection of Alewife Brook Parkway and existing Route 2. This is one of the seven terminal control points previously described in Part II. The location of the easterly control point has been determined, as a result of this Study, to be the interchange with the Inner Belt Expressway, located between Lincoln Park, Somerville, and Donnelly Field, Cambridge. The area surrounding this interchange consists of many multi-family dwellings generally located within urban renewal areas. Location of the interchange within this area provides adequate spacing between the major interchanges, and permits the extension of direct-connector ramps from the Northwest Expressway to McGrath Highway.

At the present time, there are no adequate surface streets or thoroughfares capable of accommodating the anticipated traffic within the corridor connecting the above control points. Traffic from the northwest quadrant having a destination in downtown Boston is presently forced to travel on existing Cambridge, Somerville and Boston surface streets which have the following serious limitations:

a. Narrow, heavily-congested roadways with basically two travel lanes, such as Broadway, Elm Street, Somerville Avenue, Massachusetts Avenue, Rindge Avenue, Concord Avenue, Kirkland Street and Cambridge Street, which are located in high-density residential and commercial areas. Broadway and Massachusetts Avenue have capacity for four lanes of traffic for limited distances.

b. Although major thoroughfares with four travel lanes, such as Alewife Brook Parkway, Fresh Pond Parkway, Memorial Drive, Soldiers Field Road, and Storrow Drive, partially serve the northwest areas, these roadways do not offer a continuous direct route to downtown Boston, have heavy local traffic, are used in part by traffic from the western corridor, and are also located essentially through areas of high-density residential and commercial development.

The Fitchburg Division of the Boston and Maine Railroad extends in a direct line between the two control points. The area adjacent to the railroad forms a desirable corridor for this study. Expressway locations along this general corridor provide the shortest, most direct route to a connection with the Inner Belt Expressway. By maintaining a location parallel to the railroad, a future mass transit facility could be effectively incorporated in this corridor. Locations removed from the general corridor of the railroad will have the adverse effects of passing through high-density residential developments, located both to the north and south of the railroad, and commercial activities located adjacent to Massachusetts Avenue, and also of isolating residential areas between the railroad and the Expressway.

TOPOGRAPHY AND SUBSURFACE CONDITIONS

At the easterly end of this location corridor, the Expressway is indicated above the typical Boston Basin deposits: an upper stratum of miscellaneous filled land and dense sand overlying upwards of 50 to 100 feet of blue clay, the crust of which is quite stiff before grading into the typical soft clay. Below the clay is encountered the glacial till, in turn underlain by the bedrock floor at depths varying to more than 150 feet. Near the mid-point of the route in the vicinity of Porter Square in Cambridge, the bedrock floor shelves upward toward the north and west, and the thickness of the clay deposit decreases. The hills near Porter Square, of which Spring Hill is the most predominant, consist primarily of glacial till overlain by a thin mantle of miscellaneous fill and re-worked till. West and northwest of this area, the typical clay and till deposits laid upon the bedrock floor of the Boston Basin are again encountered between Porter Square and Alewife Brook Parkway.

At Alewife Brook Parkway in the vicinity of Route 2, the depth to bedrock is quite erratic due to the presence of a buried preglacial valley system traversing the area, but is expected to be generally more than 100 feet. In some locations in this area, deposits of soft clay of considerable extent are indicated only a few feet below a surface stratum of sand and fill, while in other locations the surface deposits of granular materials above the clay are as much as 30 feet deep. The water table is generally 5 to 10 feet below the surface throughout this corridor.

LOCATIONS STUDIED

Four locations for the Northwest Expressway were studied before a selection of the Recommended and Alternate Locations was made. These four basic locations are shown on Exhibit B-5 and are referred to as follows:

Recommended Location: Porter Square-South location.
Alternate Location: Porter Square-North location.
Alternative Location A: Railroad-North location.
Alternative Location B: Railroad-South location.

DESCRIPTION OF RECOMMENDED AND ALTERNATE LOCATIONS

The Recommended Location extends southeasterly from the vicinity of Alewife Brook Parkway and existing Route 2, shown as Terminal Control Point 4, through the clay-pit area in North Cambridge, parallel to and south of the Fitchburg Division of the Boston and Maine Railroad, passes between Sears, Roebuck & Company and the railroad at Massachusetts Avenue, and continues on the south side of the railroad to an interchange with the Recommended Location of the Inner Belt Expressway located between Lincoln Park, Somerville, and Donnelly Field, Cambridge. At Porter Square the eastbound roadway is depressed and the westbound roadway is elevated over the eastbound roadway.

The Alternate Location also begins in the vicinity of Alewife Brook Parkway and existing Route 2, and extends southeasterly

through the clay pits. At Sherman Street, it crosses the Boston and Maine Railroad and continues parallel to the tracks on the northern side, crosses Massachusetts Avenue at Porter Square, recrosses the railroad at Beacon Street and continues on the south side of the railroad to an interchange with the Alternate Location of the Inner Belt Expressway north of Donnelly Field in Cambridge.

Reference should be made to the Basic Design Exhibits for the Recommended and Alternate Locations.

DESCRIPTION AND ANALYSIS OF OTHER LOCATIONS STUDIED

In addition to the Recommended and Alternate Locations, Alternative Locations A and B were considered in detail and are described below.

ALTERNATIVE LOCATION A

This location begins in the vicinity of Alewife Brook Parkway and existing Route 2, as do all locations considered, and is common to the Alternate Location as far as Walden Street. From Walden Street this alternative crosses the Boston and Maine Railroad, passes between the railroad and Sears, Roebuck & Company at Massachusetts Avenue, and rejoins the Alternate Location in the vicinity of Sacramento Street. This location offers no significant advantages over the Recommended or Alternate Locations, requires a 3,000-foot-long skewed-viaduct crossing of Walden Street, the Boston and Maine Railroad, Massachusetts Avenue and Beacon Street, and does not permit the dispersion of local-street interchanges as effectively as the Alternate Location. This location was therefore considered to be unacceptable and was discarded.

ALTERNATIVE LOCATION B

This location is common to the Recommended Location as far as Walden Street. From Walden Street this alternative continues as a depressed section, occupying the railroad right-of-way, passes under Massachusetts Avenue and between Sears, Roebuck & Company and Somerville Avenue, and rejoins the Recommended Location at Sacramento Street. Since this location requires abandonment of the railroad, which is not anticipated in the near future, it was considered unacceptable and therefore was discarded.

TABLE B-XI
NORTHWEST EXPRESSWAY
SUMMARY OF PHYSICAL EFFECTS

CITY OR TOWN: / CATEGORY	NUMBER IN CATEGORY: Recommended Location: Cambridge	Somerville	Totals	Alternate Location: Cambridge	Somerville	Totals
Use of Structures						
Residential	106	258	364	95	381	476
Retail	10	17	27	6	16	22
Wholesale	2	—	2	1	—	1
Business	3	1	4	—	1	1
Service	6	8	14	2	7	9
Institutions	1	—	1	1	1	2
Industry	4	4	8	6	6	12
Recreation	—	—	—	1	1	2
Other Data						
Vacant Lots	1	—	1	—	—	—
Households Displaced	297	557	854	181	888	1,069
Employees Displaced	145	186	331	143	354	497
Tax Loss*	$128,160	$143,720	$271,880	$79,950	$244,580	$324,530

*Based on 1961 tax rates.

ANALYSIS OF RECOMMENDED AND ALTERNATE LOCATIONS

TRAFFIC SERVICE

The Recommended Location provides complete local traffic service at two locations between Alewife Brook Parkway and the Inner Belt. A trumpet-type interchange is provided at Concord Avenue and Fresh Pond Parkway to provide traffic service for North Cambridge, East Belmont and East Watertown. Traffic assigned to the Expressway System from Fresh Pond Parkway overpasses the existing rotary at Concord Avenue to eliminate weaving with the local traffic using the Parkway and Concord Avenue. A diamond-type interchange is provided near Massachusetts Avenue to serve the Porter Square area of Cambridge and West Somerville. Continuous frontage roads are provided from Sherman Street to Beacon Street. East of Massachusetts Avenue, Beacon Street and Hampshire Street serve as a two-way frontage-road system to integrate with the frontage-road system provided for the Inner Belt. This frontage-road system will improve the traffic circulation throughout this corridor.

The Alternate Location provides traffic service to the same geographical areas as the Recommended Location. The Fresh Pond Parkway-Concord Avenue interchange is identical to that shown for the Recommended Location. A diamond-type interchange is also provided near Massachusetts Avenue to serve the Porter Square area of Cambridge and West Somerville. Limited frontage roads are provided as necessary to maintain access to property which would otherwise be isolated, but the railroad crossings required in this location preclude the provision of a continuous frontage road system.

The number of ramps provided by either location is identical; however, the flexibility of ramp placement afforded by the Recommended Location and the ability to provide a continuous frontage road system to augment the Expressway System and collect and distribute traffic, results in traffic service superior to that afforded by the Alternate Location.

TABLE B-XII
NORTHWEST EXPRESSWAY
PROJECT COSTS

In Thousands of Dollars

RECOMMENDED LOCATION

Section Number	Construction Costs: Structures	Earthwork	Pavement	Utility Relocation	Miscel-laneous	Total Construction Cost	Demolition Cost	Construction Cost Plus Demolition	Engineering and Contingencies	Right-of-Way Costs, Total Fair Market Value	Total Costs
1	$ 9,020	$1,921	$ 523	$ 250	$ 846	$ 12,560	$ 266	$ 12,826	$ 1,924	$ 3,024	$ 17,774
2	14,817	522	404	293	705	16,741	491	17,232	2,585	2,862	22,679
Totals	$ 23,837	$2,443	$ 927	$ 543	$1,551	$ 29,301	$ 757	$ 30,058	$ 4,509	$ 5,886	$ 40,453
ALTERNATE LOCATION											
1	$ 11,022	$2,823	$ 426	$ 183	$ 529	$ 14,983	$ 240	$ 15,223	$ 2,284	$ 1,838	$ 19,345
2	7,947	1,071	560	360	456	10,394	903	11,297	1,694	4,706	17,697
Totals	$ 18,969	$3,894	$ 986	$ 543	$ 985	$ 25,377	$1,143	$ 26,520	$ 3,978	$ 6,544	$ 37,042

COST SECTIONS — RECOMMENDED AND ALTERNATE LOCATIONS

1. Alewife Brook Parkway to Massachusetts Avenue
2. Massachusetts Avenue to Inner Belt Expressway

PROJECT COSTS PER MILE

	Recommended	Alternate
Number of Miles	2.5	2.8
Construction and Engineering Cost/Mile	$13,827	$10,892
Right-of-Way Cost/Mile	$ 2,354	$ 2,337
Project Cost/Mile	$16,181	$13,229

PHYSICAL AND FUNCTIONAL EFFECTS

Both the Recommended and Alternate Locations generally parallel the Fitchburg Division of the Boston and Maine Railroad with minimum effect on the service districts and urban structure of Cambridge and Somerville. The interchanges with the Inner Belt Expressway are generally located within proposed renewal areas in Cambridge and Somerville. The residences in these areas are essentially multi-family wood structures, many of which would be affected under urban renewal programs. The interchange with Fresh Pond Parkway and Concord Avenue is located within the clay-pit area in North Cambridge. These clay pits are the result of extensive brick manufacturing operations which have been discontinued. At the present time there is sufficient open area in which to locate the Expressway, but recent commercial activities indicate that the area may be developed within the next few years.

A comparison of the physical effects summarized in Table B-XI shows that fewer displacements result from the Recommended Location than from the Alternate Location. The differences are due primarily to the added length required to interchange the Alternate Location of the Northwest Expressway with the Alternate Location of the Inner Belt. The Recommended Location has decided advantages over the Alternate Location with respect to future development of the communities and integration with mass transit and the railroad. The Recommended Location is designed as a depressed roadway for a greater part of its length so that the sight of moving traffic is screened and the noise level is reduced. This design assumes retention of the railroad in its present location, but if operations are discontinued on the railroad, it is possible to maintain a depressed roadway throughout the entire length. By maintaining a location parallel to one side of the railroad, a future mass transit facility could be effectively located in this corridor. Increased accessibility afforded by the construction of the Recommended Location, provided with a continuous frontage-road system, together with sight-advertising advantages, will provide the stimulus for continued expansion of commercial and industrial activities within this corridor. The Alternate Location, which remains elevated throughout its entire length because of two railroad crossings, affects the Porter Square area and could limit the future expansion of this important shopping center.

Major roadways and expressways in the Boston Metropolitan Area have played an important role in the past development of residential, commercial and industrial activities. In this area in particular, the transportation and accessibility afforded by Alewife Brook Parkway, Route 2 and the Boston and Maine Railroad has stimulated commercial and industrial activities along Alewife Brook Parkway, Concord Avenue and Route 2 in North Cambridge. At the present time the existing street network is inadequate to handle the through-traffic in this area, thereby reducing the attractiveness of these facilities to the residents and shoppers who desire to use them. One of the most important functions of the Northwest Expressway will be to relieve the local streets of this through traffic. With local street travel thus reduced, the environment of residential and commercial areas will be greatly improved. This improved environment will, in turn, stimulate the development of new residential and commercial activities. Without the Expressway System the existing residential and commercial establishments will continue to be penalized. The net effect of construction of the Northwest Expressway will be increased accessibility to all parts of the Boston Metropolitan Area for these sections of Cambridge and Somerville. Increased accessibility will in turn increase the real value of residential and commercial properties, thereby strengthening the tax bases of these communities.

COST ANALYSIS

The summary of costs of the Recommended and Alternate Locations is presented in Table B-XII. This table shows a relatively higher construction cost for the Recommended Location, attributable to constructing a depressed roadway below permanent groundwater elevation in the Porter Square area and in the vicinity of Park and Washington Streets, requiring reinforced concrete walls and base, and membrane waterproofing.

No unusual foundation conditions are anticipated in construction of the Northwest Expressway. Along this corridor considerable unsuitable material is present. In some areas this material will have to be removed or the surface preloaded to consolidate the underlying deposits. The costs of the foundations for those structures located within the Boston Basin, where blue clay is prevalent, are based upon the use of pile construction. For those structures generally within the Porter Square area, where foundation conditions are good, the costs are based upon the use of spread footings. The design of the Recommended Location requires 2,650 feet of viaduct as compared to 3,550 feet for the Alternate Location. The Recommended Location also requires the use of approximately 1,800 feet of a depressed waterproofed section for the eastbound roadway in the Porter Square area, and 2,200 feet of this type of construction in the vicinity of Park and Washington Streets. The Alternate Location is an elevated roadway on either fill or viaduct throughout its entire length.

TABLE B-XIII
NORTHWEST EXPRESSWAY
ROAD-USER BENEFIT ANALYSIS

Item	Recommended Location	Alternate Location
Length, miles	2.5	2.8
Annual Road-User Benefit	$12,403,000	$9,535,000
Annual Cost of Expressway	$ 2,347,000	$2,164,000
Road-User Benefit Ratio	5.3	4.4

ROAD-USER BENEFIT ANALYSIS

The annual road-user benefit values, shown in Table B-XIII, more than justify the construction of either location as economically sound, and show an advantage in favor of the Recommended Location. The road-user benefit ratio, which compares travel on the new facility to existing street travel, results in a 5.3-to-one economic advantage by the use of the Recommended Location. Comparison of the annual road-user benefit values for the two locations shows incremental savings of more than $2.8 million per year for the road users in favor of the Recommended Location, which reflects the higher traffic volumes assigned thereto.

SUMMARY

Route 2, currently being designed as a limited-access expressway from Route 128 to Alewife Brook Parkway, when completed will, along with the Route 3 Expressway, be the major traffic distributor for the northwest sector of the Boston Metropolitan Area. To complete the system of circumferential and radial expressways for this area, Route 2 must be extended on new location from Alewife Brook Parkway through Cambridge and Somerville to the Inner Belt Expressway. At the present time there are no roadways along this corridor that are capable of accommodating the anticipated traffic.

Traffic from the northwest sector must presently travel on limited-capacity streets located in high-density residential and commercial areas of Cambridge and Somerville. The attractiveness of the commercial and residential areas is diminished, because of the heavy volumes of through-traffic that now must travel on the local streets. These streets must be relieved of the burden of through-traffic to stimulate commercial activity and to improve the environment of the area for residential use.

Construction of the Northwest Expressway in the Recommended Location will:

a. Provide efficient traffic service and maximum flexibility for traffic distribution in this corridor, due to the ramp locations and by the provision of a continuous frontage-road system to augment the Expressway.

b. Cause less displacement of families and employees, cause fewer residential structures to be demolished, result in a smaller cost of right-of-way acquistion, and a smaller total tax loss to Cambridge and Somerville than would the Alternate Location.

c. Result in approximately $12.4 million in direct annual savings to the road users by use of the Expressway in lieu of use of the existing street network, or $2.8 million more than the annual savings provided by the Alternate Location.

Construction of the Northwest Expressway and its integration with the Expressway System presents an opportunity for Cambridge and Somerville to undertake a program of urban renewal, with concurrent residential, commercial and industrial developments which will greatly strengthen the communities' economic positions by more productive and efficient land use.

SECTION 5 – THE NORTHERN EXPRESSWAY

GENERAL

Interstate Route 93, when completed, will serve northern New England from Boston, Massachusetts, to St. Johnsbury, Vermont, via central New Hampshire. The Northern Expressway will be part of this route. The northerly control point for this Study, shown as Terminal Control Point 6 on Exhibit L-1, has been established as the end of the present construction of Interstate Route 93 in Medford. This is one of the seven terminal control points previously outlined in Part II. The location of the southerly control point was established, as a result of this Study, to be the interchange of the Northern Expressway with the Inner Belt Expressway. The Recommended Location of the interchange is centered in an industrial and commercial complex located between Washington Street and the Boston and Maine Railroad yards, at the Somerville-Boston City Line. Many of the structures located in this area are in poor condition. The Alternate Location of the interchange is in a residential area for which urban renewal is planned, between Broadway and Washington Street near the Somerville-Boston City Line.

At the present time there are no adequate major thoroughfares capable of accommodating the anticipated traffic within the corridor connecting these control points. All traffic is now forced to use sections of the Mystic Valley Parkway, Mystic Avenue, Broadway, McGrath Highway and Rutherford Avenue. In many places, only one lane is available for moving traffic in each direction, thereby causing serious congestion and delay.

The corridor of study contains numerous existing or proposed developments which have a particularly important bearing on the location of the Expressway. These developments are the Mystic River Basin as proposed by the Metropolitan District Commission, public housing, St. Polycarp's and St. Benedict's Churches, Foss Park, First National Stores storage warehouses, and the Boston and Maine Railroad.

TOPOGRAPHY AND SUBSURFACE CONDITIONS

The northerly half of the expressway is located within the flood plain deposits of the Mystic River Basin. Previous boring data indicates 10 to 20 feet of very soft peat and organic river silts overlying the typical blue clay deposits of varying depth. Glacial till of varying thickness is generally encountered beneath the clay. Depth to bedrock is erratic due to the presence of pre-glacial rock valleys and gorges which traverse the area, but maximum depths of about 150 feet should be anticipated with an average of approximately 60 feet. Much of this area has miscellaneous fill of recent origin overlying these native deposits.

For the southerly portion of the expressway extending from the edge of the Mystic River Basin to the Inner Belt interchange area, sub-surface investigations generally indicate surface deposits of 30 to 50 feet of fluvio-glacial sand and glacial till overlying relatively shallow bedrock. Localized deposits of clay have been encountered in this portion, particularly near Foss Park west of Mystic Avenue and also at the Boston and Maine Railroad yards off Washington Street. The latter deposit appears to follow a remnant of the pre-glacial valley system beneath the interchange area.

LOCATIONS STUDIED

The limited length of the Expressway, land-use restrictions, and traffic service requirements restrict the number of possible locations of this Expressway. In the Ten Hills Area, the only locations for the Expressway are on either side of Ten Hills, one between Bailey Road and Mystic Avenue, the other between Shore Drive and Wellington Bridge. Southeasterly of Ten Hills, three locations are possible: one parallel to Mystic Avenue, one parallel to Middlesex Avenue, and one along the Boston and Maine Railroad. The three basic locations are shown on Exhibit B-6 and are referred to as follows:

Recommended Location: Mystic Avenue location.
Alternate Location: Middlesex Avenue location.
Alternative Location A: Boston and Maine Railroad location.

DESCRIPTION OF RECOMMENDED AND ALTERNATE LOCATIONS

The Recommended Location extends southeasterly from the end of the present construction of Interstate Route 93 in the vicinity of the Mystic Valley Parkway in Medford, across the marshes of the Mystic River Reservation. It parallels Mystic Avenue, and after entering Somerville continues southeasterly between Bailey Road and Mystic Avenue to the Fellsway (U.S. Route 1). From the Fellsway the location extends southeasterly, across Mystic Avenue and Broadway, to a directional interchange with the Recommended Location of the Inner Belt.

The Alternate Location begins at the same point as the Recommended Location and proceeds easterly across the Mystic River Reservation, continues southerly over Shore Drive and the Fellsway, proceeds parallel to and just west of Middlesex Avenue, crosses Mystic Avenue and Broadway, and extends to a directional interchange with the Alternate Location of the Inner Belt.

Reference should be made to the Basic Design Exhibits for the Recommended and Alternate Locations.

DESCRIPTION AND ANALYSIS OF OTHER LOCATIONS STUDIED

ALTERNATIVE LOCATION A

This location is common to the Alternate Location as far as the vicinity of the Fellsway and Shore Drive. After crossing the Fellsway it extends easterly along the banks of the Mystic River, and continues southerly, as a viaduct structure, over the tracks of the Portland Division of the Boston and Maine Railroad. It parallels the railroad, overpassing the Mystic Avenue and Broadway bridges, and interchanges with the Inner Belt in the Boston and Maine Railroad yards.

In this location, the lack of local surface streets and the proximity of large commercial and industrial developments adjacent to the railroad and the Mystic River preclude the provision of adequate local traffic service. This alternative also limits the use of the Mystic River Basin for recreational purposes, and requires an extensive viaduct section in order to maintain operations on the Boston and Maine Railroad. For these reasons, this location was considered unacceptable and was therefore discarded.

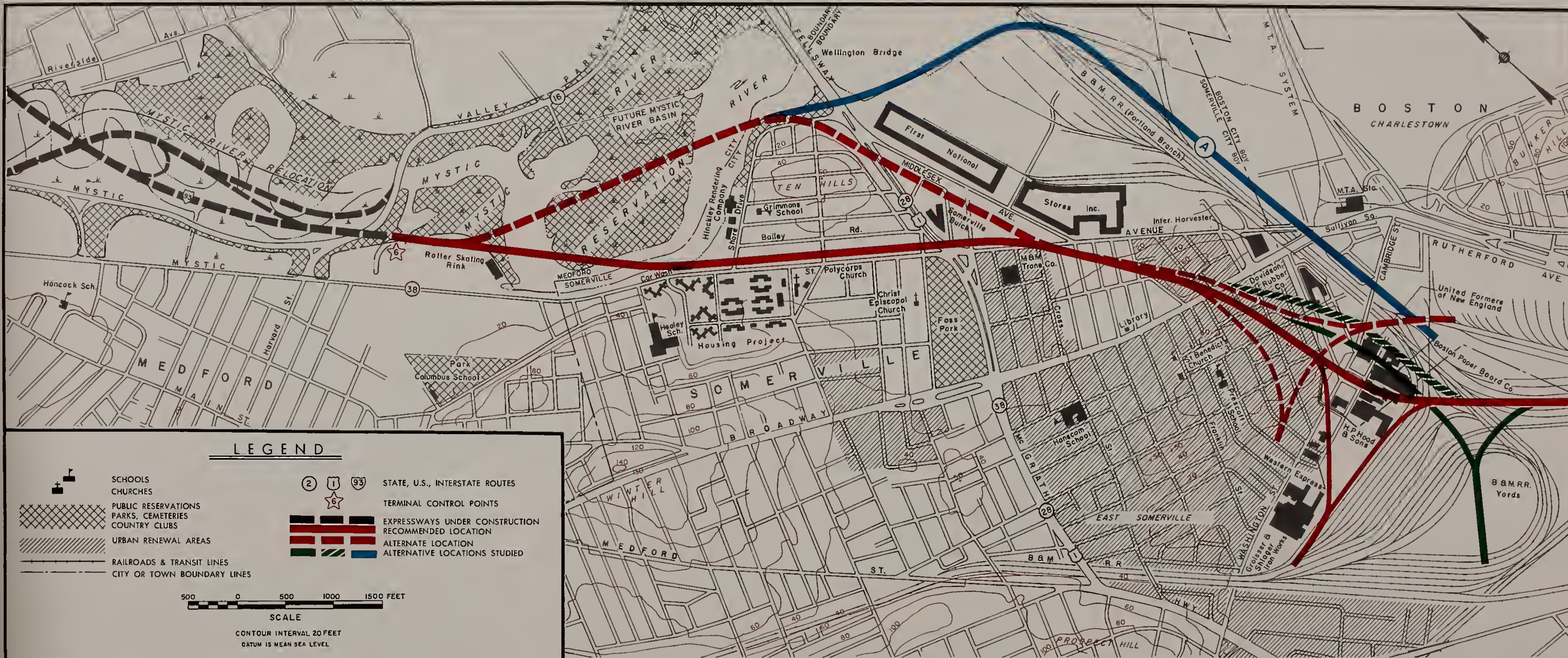


Exhibit B-6

NORTHERN EXPRESSWAY STUDY LINES

ANALYSIS OF RECOMMENDED AND ALTERNATE LOCATIONS

TRAFFIC SERVICE

The Recommended Location of the Northern Expressway extends from the Interstate Route 93 interchange now under construction in Medford, to an interchange with the Inner Belt south of Broadway, Somerville. A complete local-service interchange serving Somerville and Medford is provided in the vicinity of Foss Park. Traffic service is provided between the Northern Expressway and the Sullivan Square overpass, to permit direct access to Charlestown and the North Terminal area via Rutherford Avenue and its extension to City Square, Charlestown, without requiring travel on the Inner Belt. Revisions to the local street pattern as shown on the Basic Design Exhibits, together with a coordinated signal system, are recommended to accommodate the assigned ramp traffic, and to facilitate distribution of this traffic to the existing arterial streets. Frontage roads are provided to maintain continuity of the local street system. The Recommended Location local-service interchange at the Fellsway is a split-diamond type, with the expressway ramps terminating at frontage roads on either side of the Fellsway, thereby providing for maximum flexibility of traffic distribution to the local street network in this area.

The Alternate Location provides traffic service to the same geographical areas as the Recommended Location. However, the local service interchange in the triangular area bounded by the Fellsway, Mystic Avenue, and Middlesex Avenue does not permit the distribution of assigned ramp traffic to the major arterial streets as well as does the interchange for the Recommended Location. Traffic service to the Sullivan Square area is identical with that of the Recommended Location, with frontage roads provided to maintain continuity of the local street system.

PHYSICAL AND FUNCTIONAL EFFECTS

The Recommended Location extends closer to Boston than the Alternate Location, thereby increasing the physical effects of the Recommended Location over those of the Alternate Location. However, the physical and functional effects associated with the Inner Belt favor the Recommended Location of the interchange with the Northern Expressway over the Alternate Location, and therefore must be considered in the over-all analysis of the most advantageous location of this section of the Expressway System. The Recommended Location causes a minimal effect on future use of the Mystic River Basin. The Alternate Location passes through the middle of this basin and has a detrimental effect on this proposed development. While the use of viaduct would not deplete the storage volume of the basin for flood control purposes, it would seriously impair the use of the basin for recreational purposes.

The Inner Belt interchange for the Recommended Location is primarily located in the railroad yards and in the industrial and commercial area adjacent to the yards. This location has the least effect on nearby residential areas. The Inner Belt interchange for the Alternate Location affects the residential area between Broadway and Washington Street, but has less effect on business and industry.

The physical effects of construction of either location in Medford, as shown in Table B-XIV, do not impair the physical structure of that city, since these locations are along the Mystic River Valley.

Non-users of the Expressway will derive both tangible and intangible benefits. A properly designed, landscaped, and maintained expressway system tends to increase the value of real estate in its corridor of influence. With adequate access and egress ramps, new business will be generated by the road users. Long-time gains will be realized by the cities of Medford and Somerville by virtue of the stimulated economies of neighborhood businesses and the certainty of renewed interest and activity in areas of commercial and industrial development.

The City of Somerville is currently planning to correlate urban renewal and commercial and industrial developments with the Expressway. This includes a major renewal project bounded by McGrath Highway, Broadway, and the Northern Expressway. A commercial development is planned for the area bounded by McGrath Highway, Broadway, Cross Street East, and the Northern Expressway at Mystic Avenue. Industrial development is proposed

TABLE B-XIV
NORTHERN EXPRESSWAY
SUMMARY OF PHYSICAL EFFECTS

	NUMBER IN CATEGORY					
	Recommended Location			Alternate Location		
CITY OR TOWN: / CATEGORY	Somerville	Medford	Totals	Somerville	Medford	Totals
Use of Structures						
Residential	193	—	193	147	—	147
Retail	26	—	26	9	—	9
Wholesale	2	—	2	—	—	—
Business	1	—	1	—	—	—
Service	17	—	17	3	—	3
Institutions	1	—	1	—	—	—
Industry	5	—	5	7	—	7
Recreation	—	1	1	—	1	1
Other Data						
Vacant Lots	—	1	1	—	1	1
Households Displaced	503	—	503	396	—	396
Employees Displaced	250	—	250	229	—	229
Tax Loss*	$213,390	$3,020	$216,410	$141,860	$3,020	$144,880

*Based on 1961 tax rates.

TABLE B-XV
NORTHERN EXPRESSWAY
PROJECT COSTS

In Thousands of Dollars

RECOMMENDED LOCATION

Section Number	Construction Costs: Structures	Earthwork	Pavement	Utility Relocation	Miscel-laneous	Total Construction Cost	Demolition Cost	Construction Cost Plus Demolition	Engineering and Contingencies	Right-of-Way Costs, Total Fair Market Value	Total Costs
1	$ 585	$2,322	$ 479	$ 90	$ 365	$ 3,841	$ 89	$ 3,930	$ 590	$ 636	$ 5,156
2	5,331	541	205	70	211	6,358	241	6,599	990	2,773	10,362
3	1,115	61	49	35	53	1,313	58	1,371	206	633	2,210
Totals	$ 7,031	$2,924	$ 733	$ 195	$ 629	$ 11,512	$ 388	$ 11,900	$ 1,786	$ 4,042	$ 17,728

ALTERNATE LOCATION

Section Number	Construction Costs: Structures	Earthwork	Pavement	Utility Relocation	Miscel-laneous	Total Construction Cost	Demolition Cost	Construction Cost Plus Demolition	Engineering and Contingencies	Right-of-Way Costs, Total Fair Market Value	Total Costs
1	$ 2,790	$4,592	$ 425	$ 35	$ 247	$ 8,089	$ 13	$ 8,102	$ 1,215	$ 375	$ 9,692
2	2,172	248	158	62	125	2,765	46	2,811	422	585	3,818
3	2,149	218	168	68	155	2,758	239	2,997	450	1,756	5,203
Totals	$ 7,111	$5,058	$ 751	$ 165	$ 527	$ 13,612	$ 298	$ 13,910	$ 2,087	$ 2,716	$ 18,713

COST SECTIONS — Recommended Location

1. Mystic Volley Porkwoy to the Fellswoy
2. Fellswoy to Broodwoy
3. Broodwoy to Perkins Street

Alternate Location

1. Mystic Volley Parkwoy to the Fellswoy
2. Fellswoy to Mystic Avenue
3. Mystic Avenue to Broodwoy

PROJECT COSTS PER MILE

	Recommended	Alternate
Number of Miles	1.8	1.7
Construction and Engineering Cost/Mile	$7,603	$ 9,410
Right-of-Woy Cost/Mile	$2,246	$ 1,598
Project Cost/Mile	$9,849	$11,008

for areas located to the east of the Expressway, adjacent to the Somerville-Boston City Line. The net effect of the Expressway will be to increase the tax base of Somerville, so that the temporary loss resulting from the displacement of properties will be more than regained.

COST ANALYSIS

The summary of costs of the Recommended and Alternate Locations is presented in Table B-XV. This table shows a higher construction cost for the Alternate Location, primarily attributable to the required excavation of considerable unsuitable material in the Mystic River Basin and its replacement with granular material. No unusual foundation conditions are anticipated for the construction of this Expressway. The costs of the foundations for those structures located to the north and west of Ten Hills, where blue clay is prevalent, are based upon the use of pile construction. For those structures located within the Ten Hills area and from the Ten Hills area to the Inner Belt, where foundation conditions are good, the costs are based upon the use of spread footings. The design of the Recommended Location requires 1,700 feet of viaduct as compared to 1,500 feet for the Alternate Location. The Recommended Location also requires the rechanneling of 1,800 feet of the Mystic River, while 2,500 feet of rechanneling are required for the Alternate Location.

ROAD-USER BENEFIT ANALYSIS

The results of the road-user benefit analyses as applied to

the Recommended and Alternate Locations of the Northern Expressway are shown in Table B-XVI. The road-user benefit analyses more than justify the construction of either the Recommended or Alternate Location as economically sound. The road-user benefit ratio shows about a 3.9-to-one economic advantage by use of the Recommended Location rather than the existing surface street network. The road-user benefit ratio for the Alternate Location shows a 3.3-to-one economic advantage. Comparison of the annual road-user benefits and the annual costs shows an economic advantage in favor of the Recommended Location by virtue of greater annual benefits with less annual costs.

TABLE B-XVI
NORTHERN EXPRESSWAY
ROAD-USER BENEFIT ANALYSIS

Item	Recommended Location	Alternate Location
Length, miles	1.8	1.7
Annual Road-User Benefit	$4,029,000	$3,677,000
Annual Cost of Expressway	$1,034,000	$1,102,000
Road-User Benefit Ratio	3.9	3.3

SUMMARY

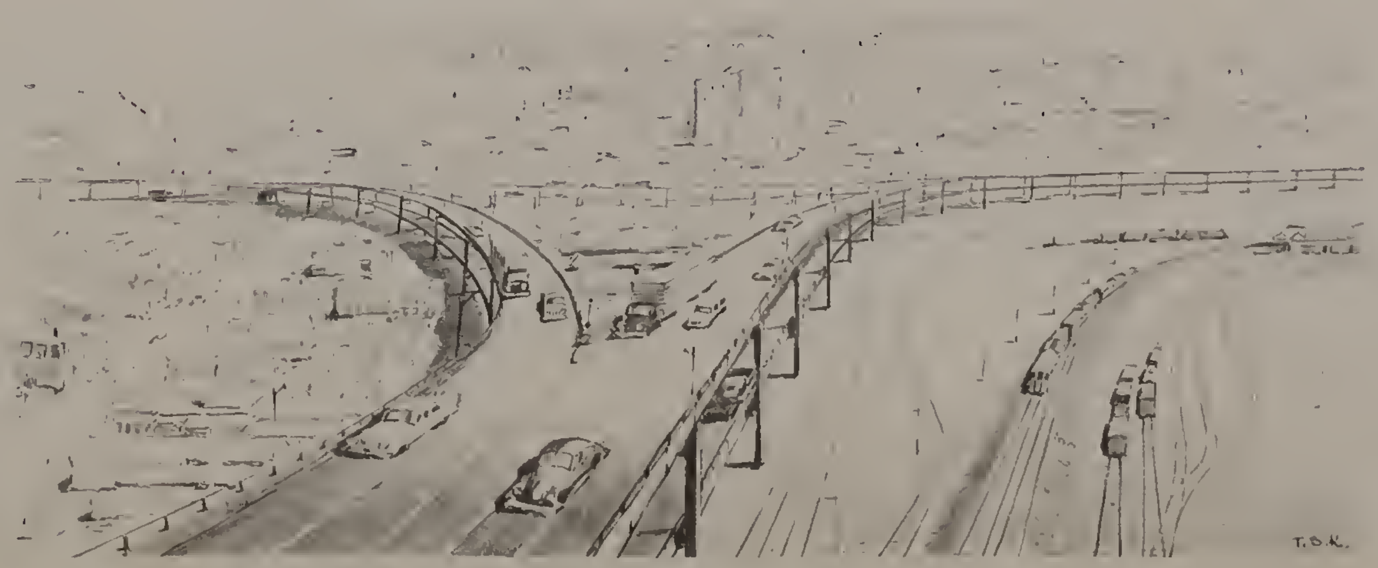
Interstate Route 93, which extends from Boston through New Hampshire to St. Johnsbury, Vermont, has been constructed from the New Hampshire State Line to Medford Square; a one-mile section from Medford Square to the Mystic Valley Parkway, near the Somerville City Line, is presently under construction. The completion of the Northern Expressway to the Mystic Valley Parkway will induce heavy volumes of through-traffic to travel on existing streets in Somerville, which are limited in capacity and not adequate to handle the anticipated traffic.

Interstate Route 93 must be extended southeasterly to the Inner Belt to complete this radial expressway. Completion of the Northern Expressway will relieve the existing streets of their burden of through-traffic, thereby improving the environment of commercial and residential activities. With the attractiveness of the area improved by removal of through-traffic, there will be a concomitant increase in the real value of commercial and residential property and a necessary stimulus for commercial and industrial development.

Construction of the Northern Expressway in the Recommended Location will:

a. Provide maximum flexibility of traffic distribution to the local street network.
b. Provide more efficient traffic service for $1 million less total cost than the Alternate Location.
c. Result in approximately $4 million in direct annual savings to the road users by use of the Expressway in lieu of the existing street network.
d. Permit development of an attractive fresh-water basin in the Mystic River estuary for flood control purposes and recreational activities, whereas the Alternate Location would not permit the development of the basin for recreational activities.

Construction of the Northern Expressway and its integration with the Expressway System presents an opportunity for Somerville to advance its urban renewal program and to realize effectively its over-all community objective of commercial and industrial expansion. The successful completion of the Expressway System will increase the value of Somerville's existing commercial and industrial facilities and encourage the development of new activities. The development of new industry and the expansion of existing industry will improve the present imbalance of the economy in Somerville.



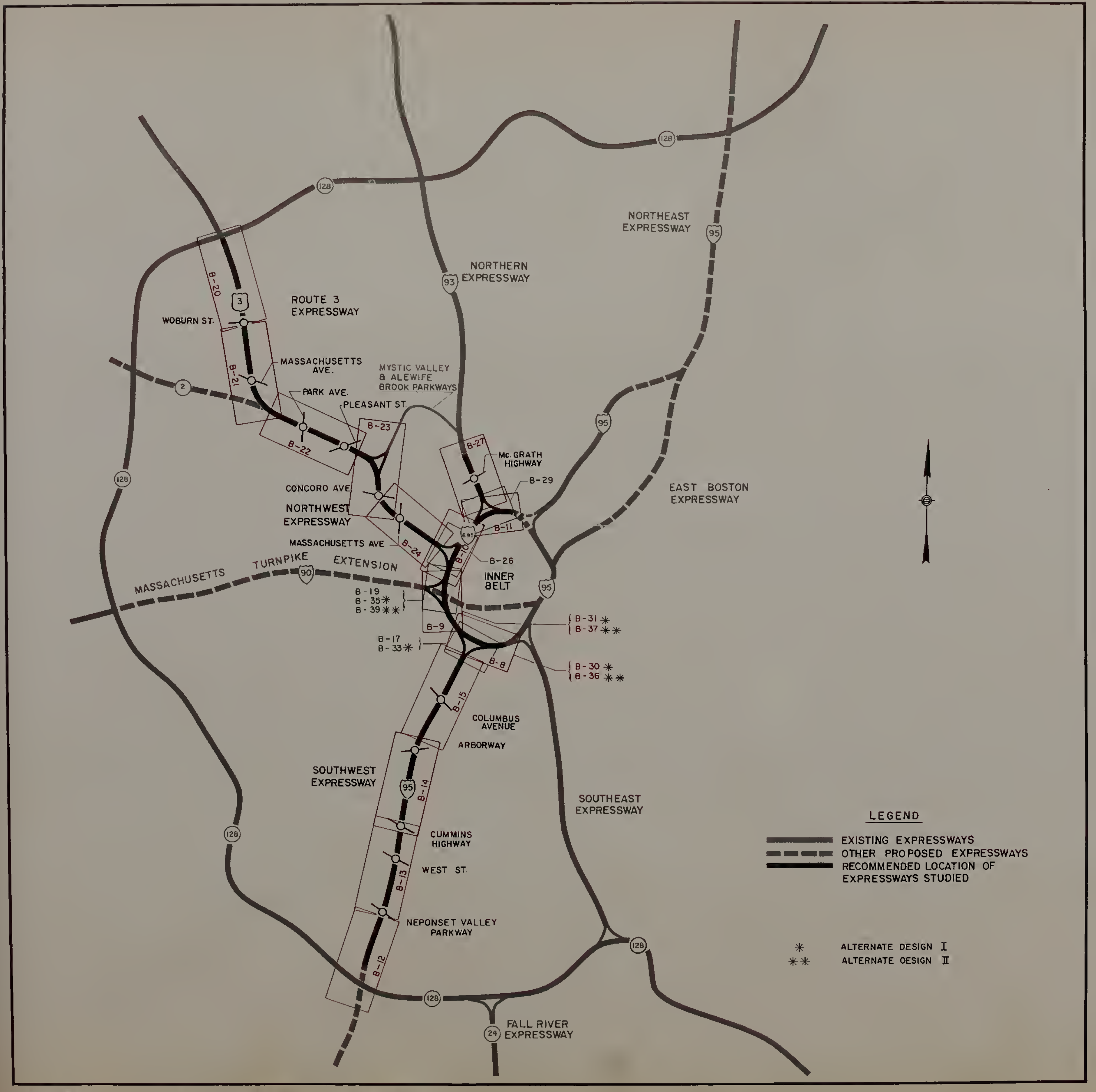
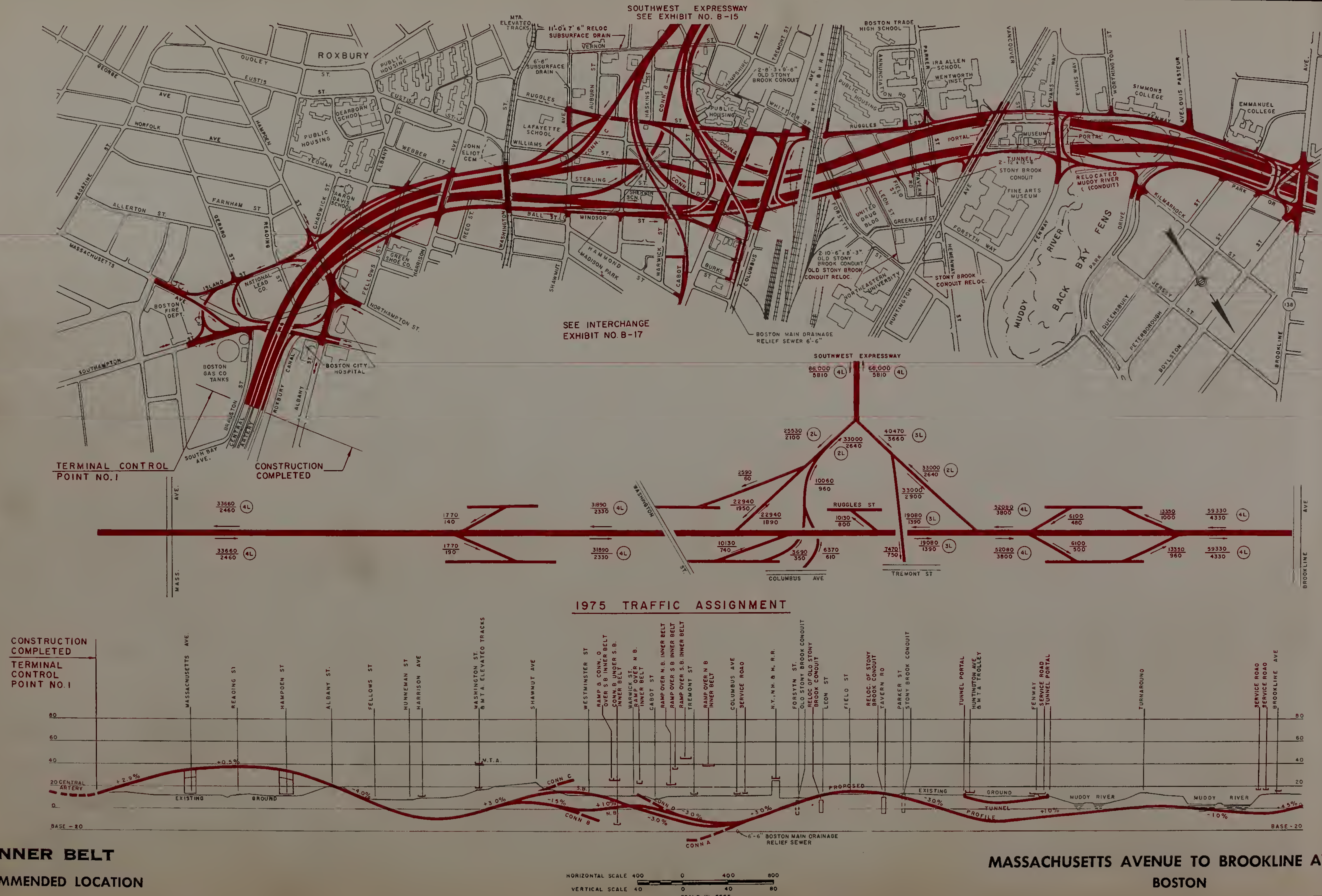


EXHIBIT B-7
KEY MAP
RECOMMENDED LOCATION

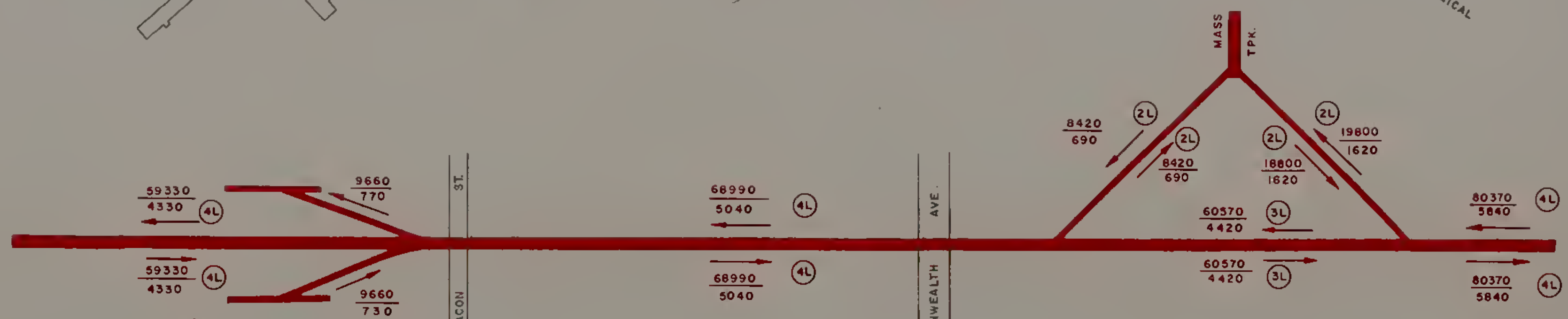


INNER BELT

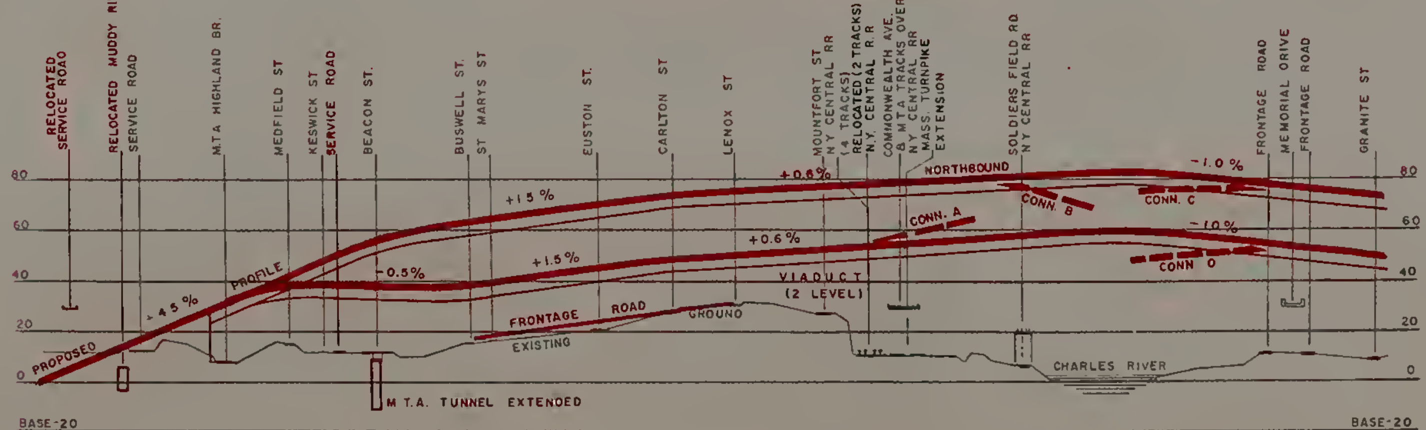
RECOMMENDED LOCATION

MASSACHUSETTS AVENUE TO BROOKLINE AVENUE

BOSTON



1975 TRAFFIC ASSIGNMENT



HORIZONTAL SCALE 400 0 400 800

VERTICAL SCALE 40 0 40 80

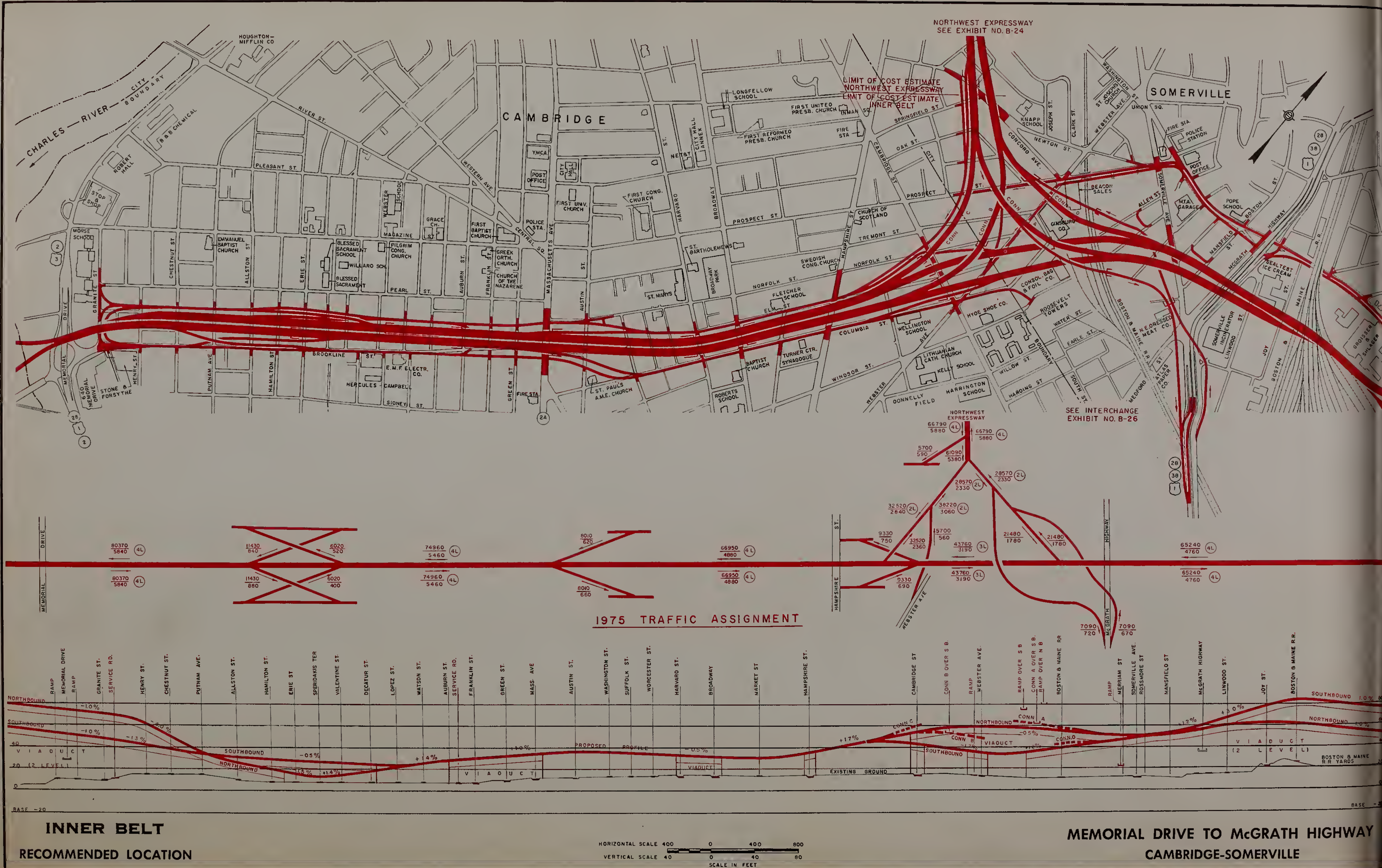
SCALE IN FEET

BROOKLINE AVENUE TO MEMORIAL DRIVE

BOSTON-BROOKLINE-CAMBRIDGE

INNER BELT

RECOMMENDED LOCATION

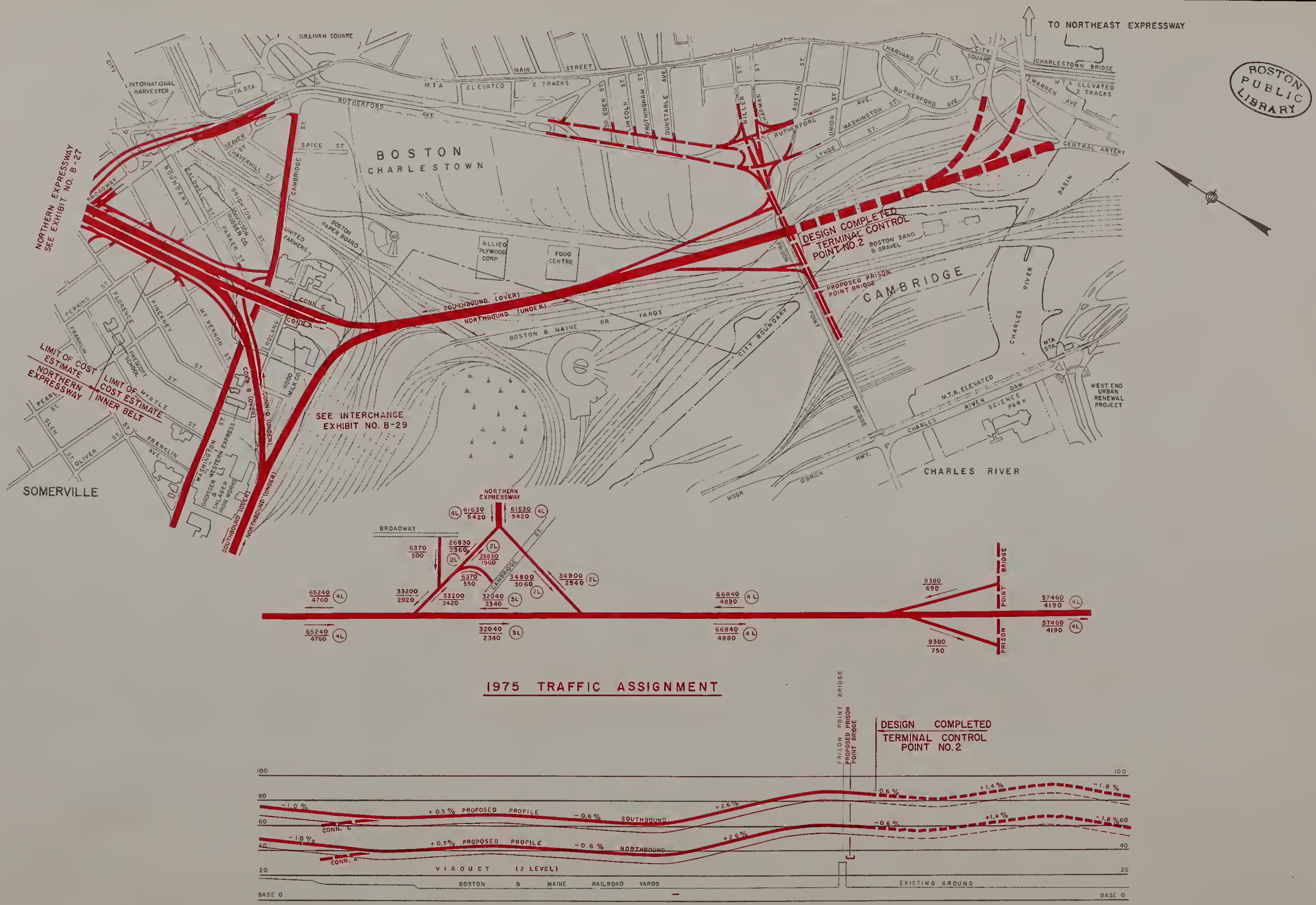


INNER BELT

RECOMMENDED LOCATION

MEMORIAL DRIVE TO McGRATH HIGHWAY

CAMBRIDGE-SOMERVILLE



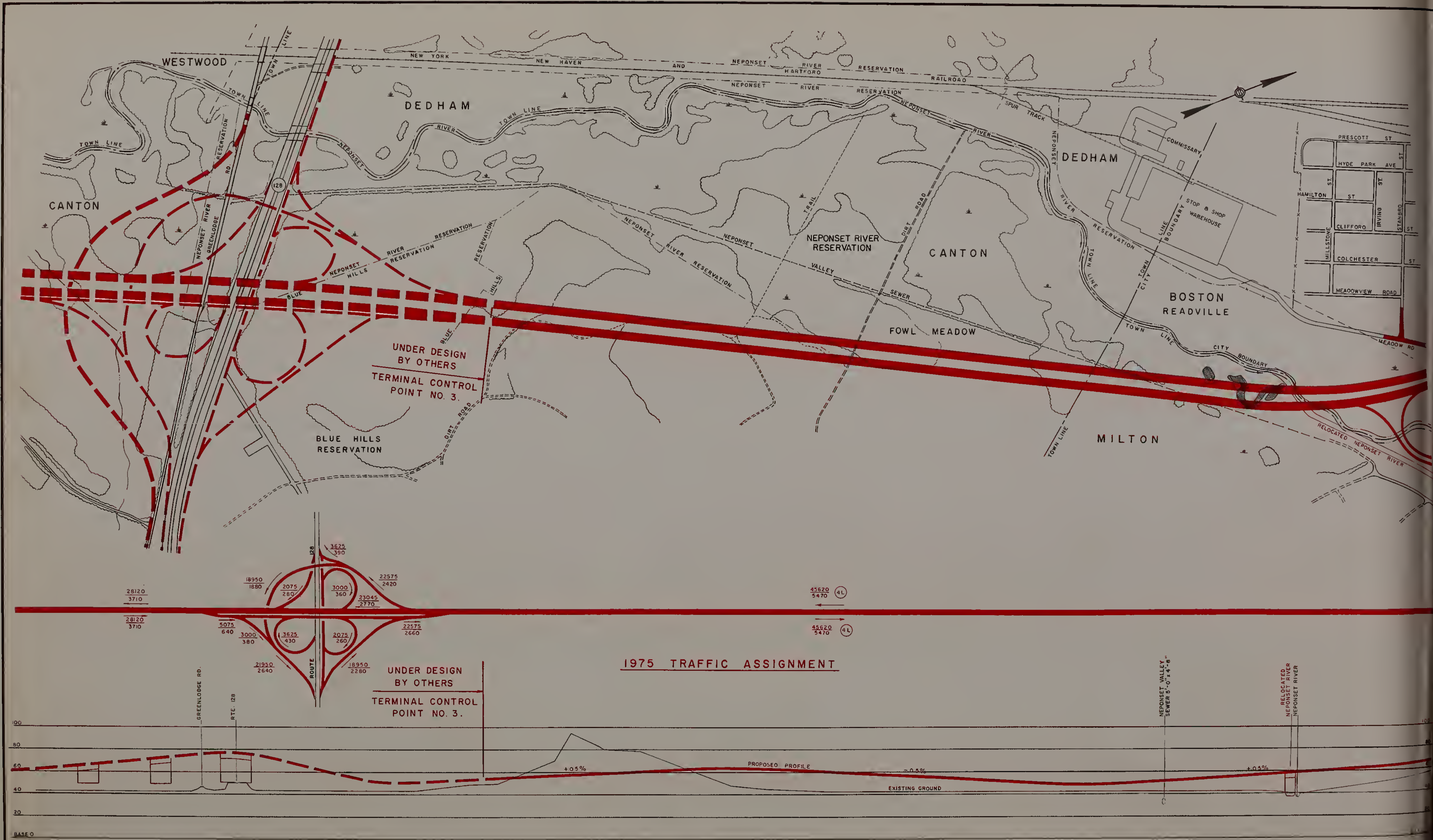
McGRATH HIGHWAY TO PRISON POINT BRIDGE

SOMERVILLE-BOSTON

HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

INNER BELT

RECOMMENDED LOCATION



SOUTHWEST EXPRESSWAY

RECOMMENDED LOCATION

ROUTE 128 TO NEPONSET VALLEY PARKWAY

CANTON-MILTON-BOSTON

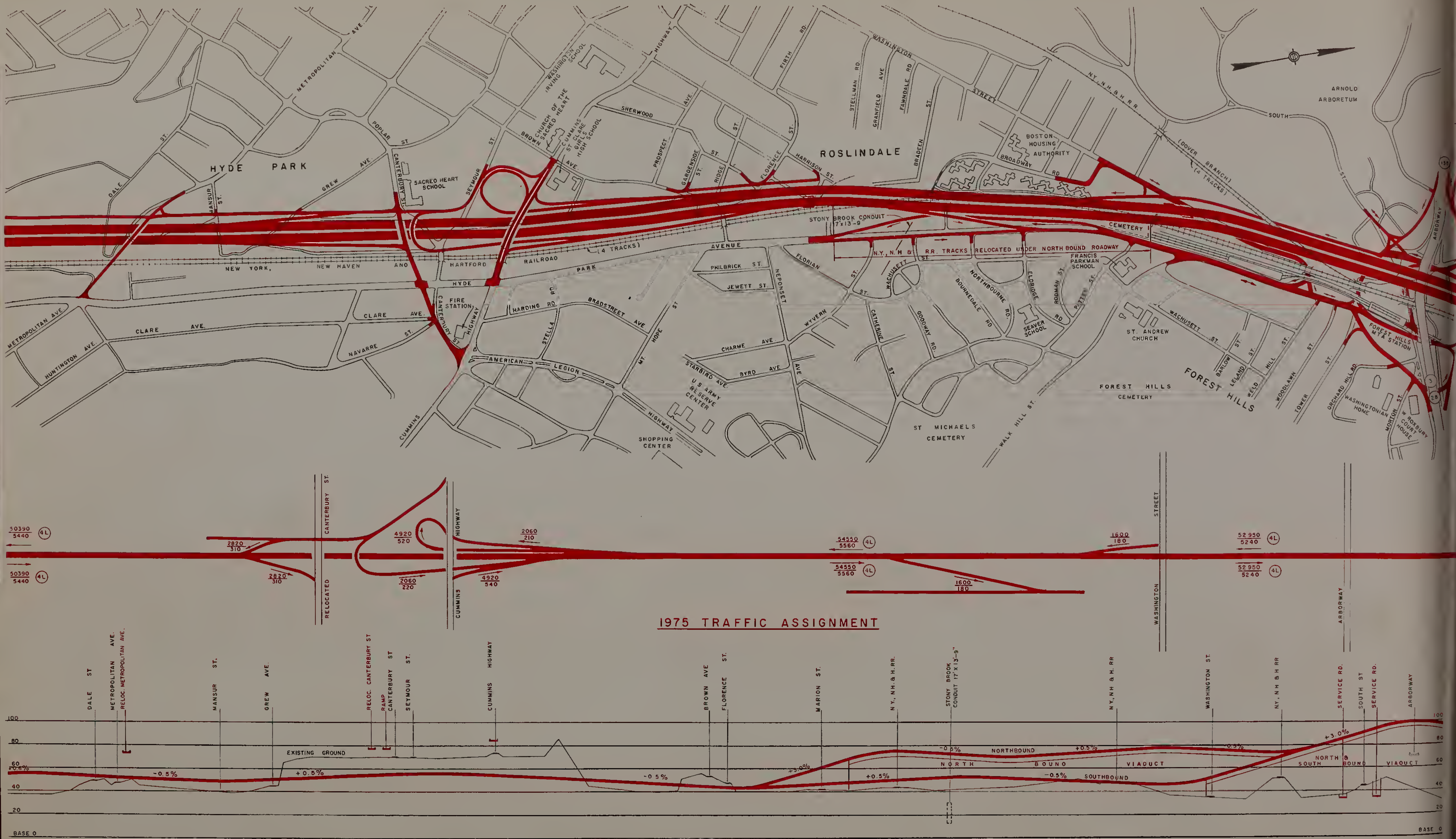
NEPONSET VALLEY PARKWAY TO METROPOLITAN AVENUE

BOSTON

HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

SOUTHWEST EXPRESSWAY

RECOMMENDED LOCATION



SOUTHWEST EXPRESSWAY

RECOMMENDED LOCATION

HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

METROPOLITAN AVENUE TO THE ARBORWAY

BOSTON

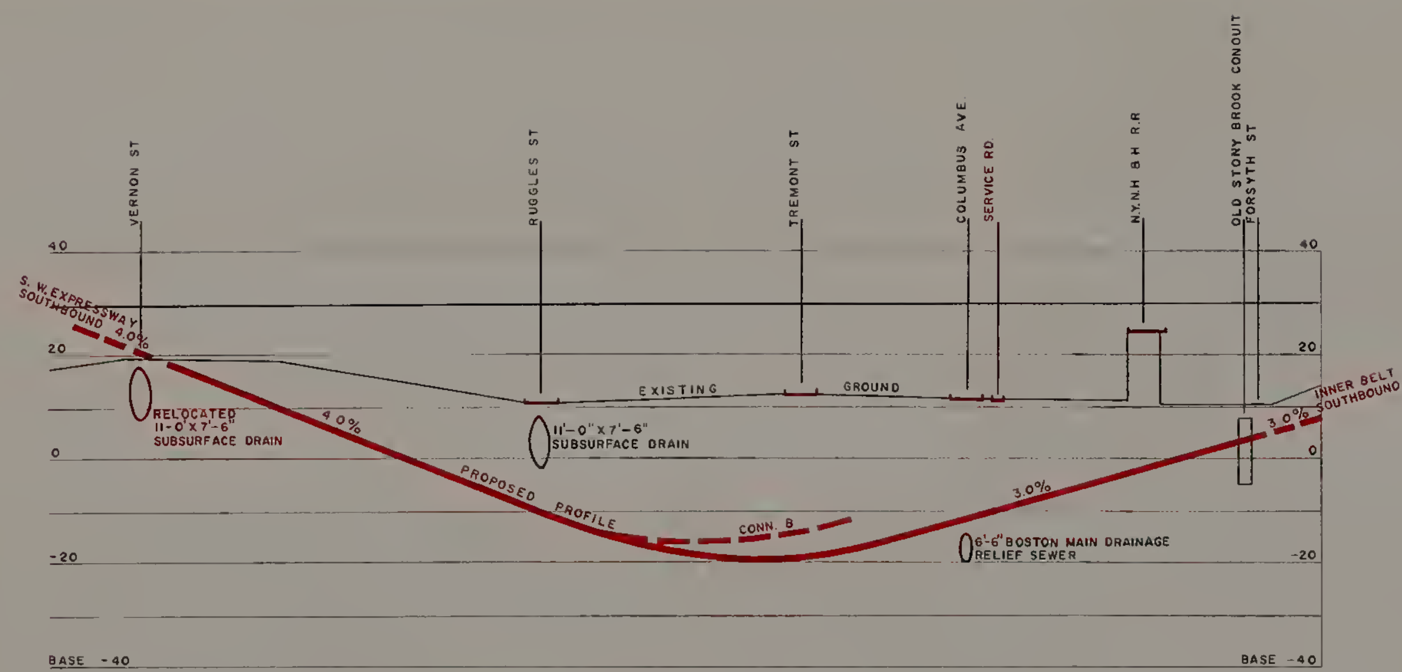
EXHIBIT B-15

THE ARBORWAY TO VERNON STREET

BOSTON

SOUTHWEST EXPRESSWAY

RECOMMENDED LOCATION



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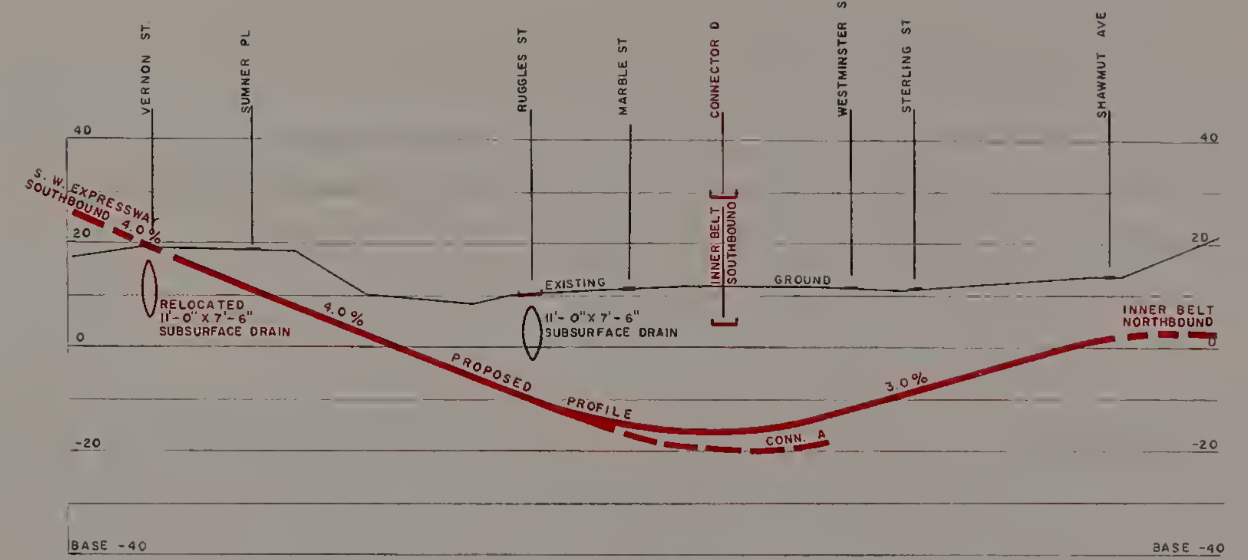

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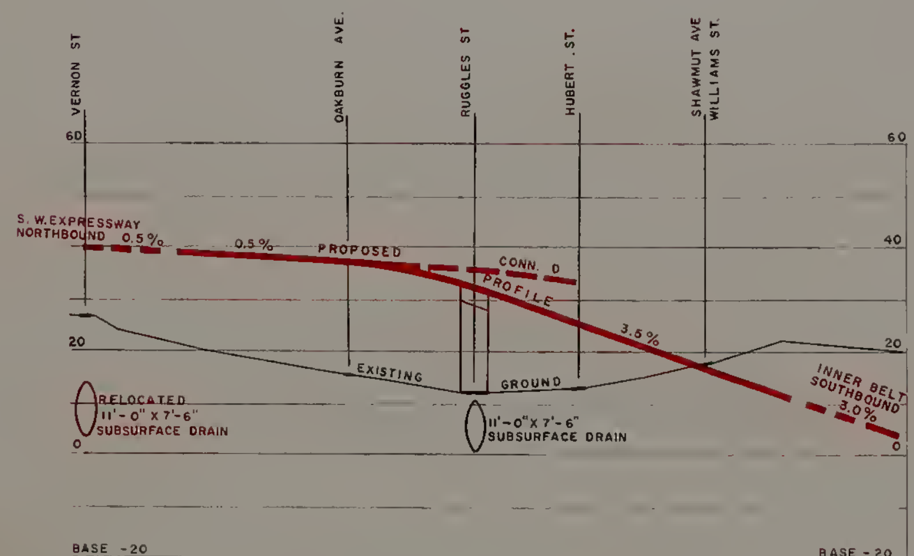

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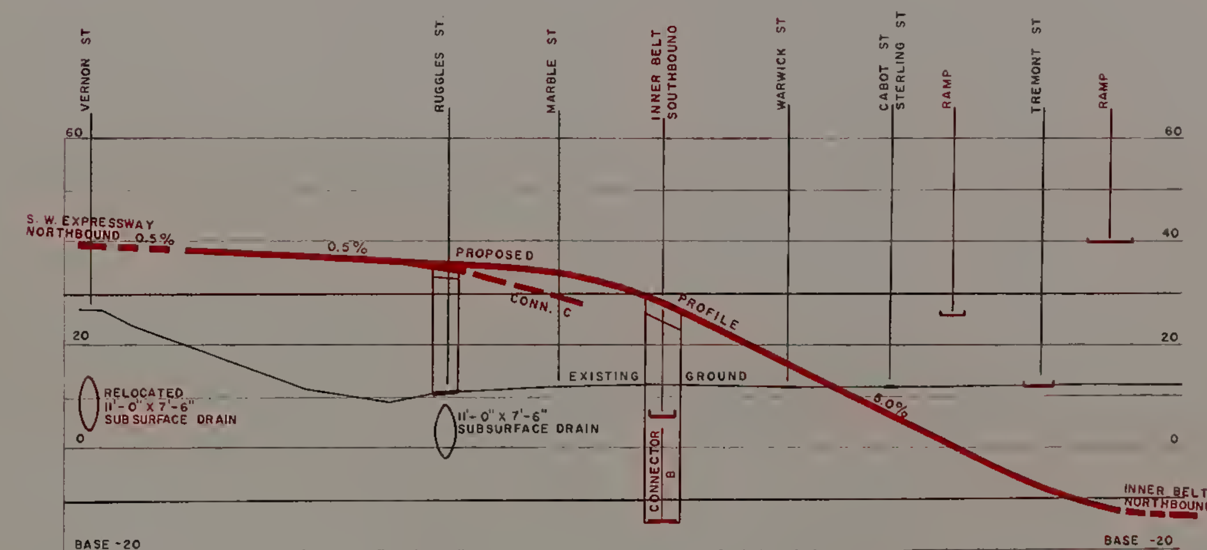


CONNECTOR D

SOUTHWEST EXPRESSWAY AND INNER BELT

RECOMMENDED LOCATION

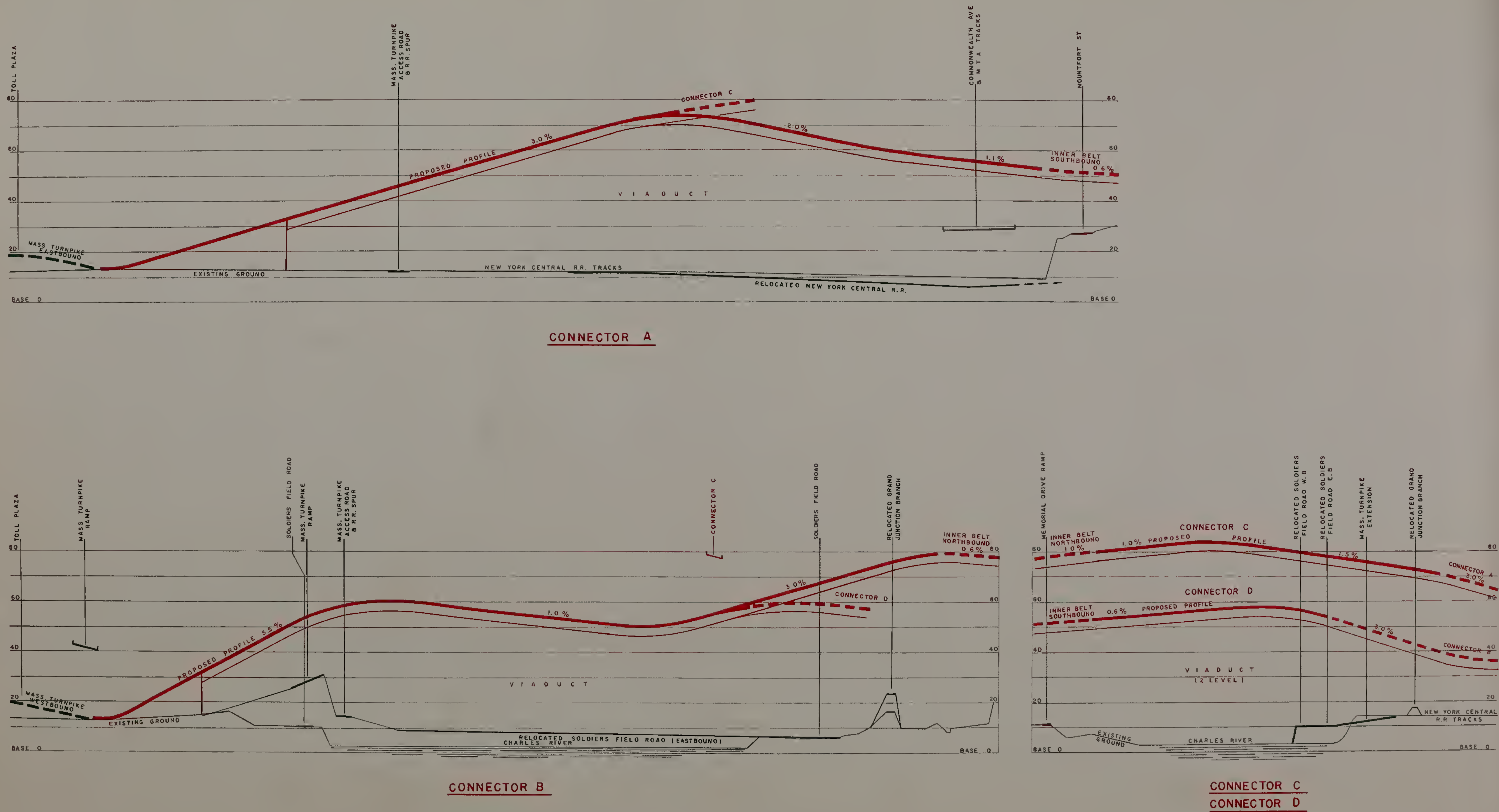
HORIZONTAL SCALE 200 0 200 400
VERTICAL SCALE 20 0 20 40
SCALE IN FEET

INTERCHANGE PROFILES

BOSTON

INTERCHANGE PLAN
BOSTON

SOUTHWEST EXPRESSWAY AND INNER BELT
RECOMMENDED LOCATION



INNER BELT AND MASSACHUSETTS TURNPIKE

RECOMMENDED LOCATION

HORIZONTAL SCALE 200 0 200 400
VERTICAL SCALE 20 0 20 40
SCALE IN FEET

INTERCHANGE PROFILES

BOSTON-BROOKLINE-CAMBRIDGE

INTERCHANGE PLAN
BOSTON-BROOKLINE-CAMBRIDGE

INNER BELT AND MASSACHUSETTS TURNPIKE
RECOMMENDED LOCATION

ROUTE 3 EXPRESSWAY

RECOMMENDED LOCATION

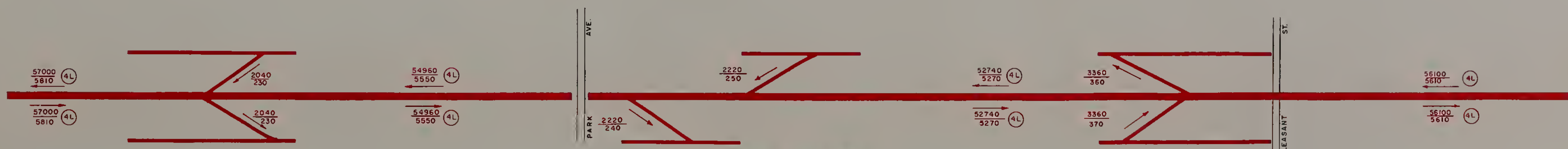
ROUTE 128 TO WOBURN STREET

BURLINGTON-LEXINGTON

WOBURN STREET TO APPLETON STREET
LEXINGTON-ARLINGTON

HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

ROUTE 3 EXPRESSWAY
RECOMMENDED LOCATION



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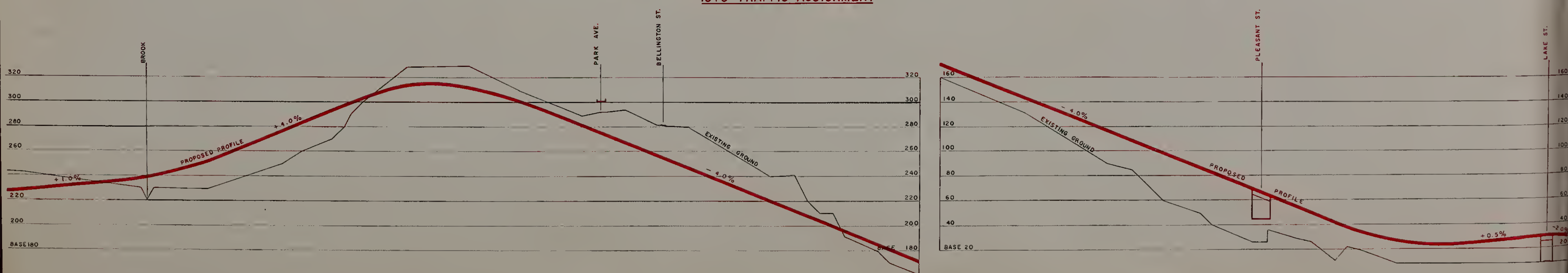


ROUTE 3 EXPRESSWAY

RECOMMENDED LOCATION

HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

APPLETON STREET TO LAKE STREET

ARLINGTON-BELMONT

LAKE STREET TO SHERMAN STREET

BELMONT-ARLINGTON-CAMBRIDGE

HORIZONTAL SCALE 400 0 400 800

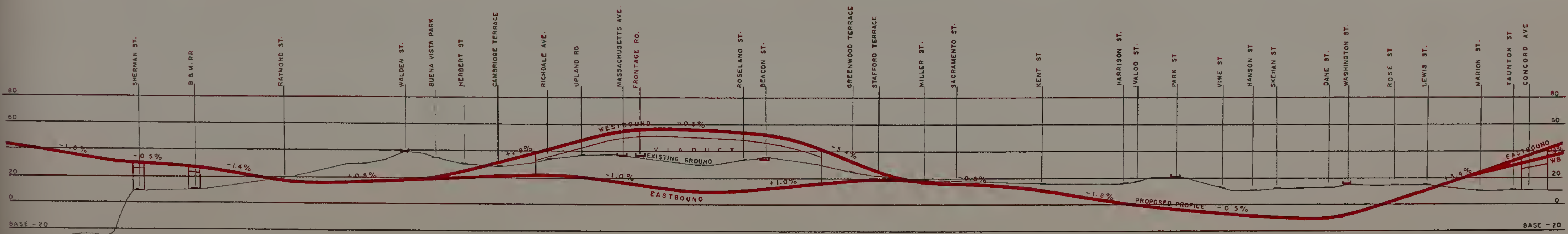
VERTICAL SCALE 40 0 40 80

SCALE IN FEET

ROUTE 3 EXPRESSWAY — NORTHWEST EXPRESSWAY

RECOMMENDED LOCATION

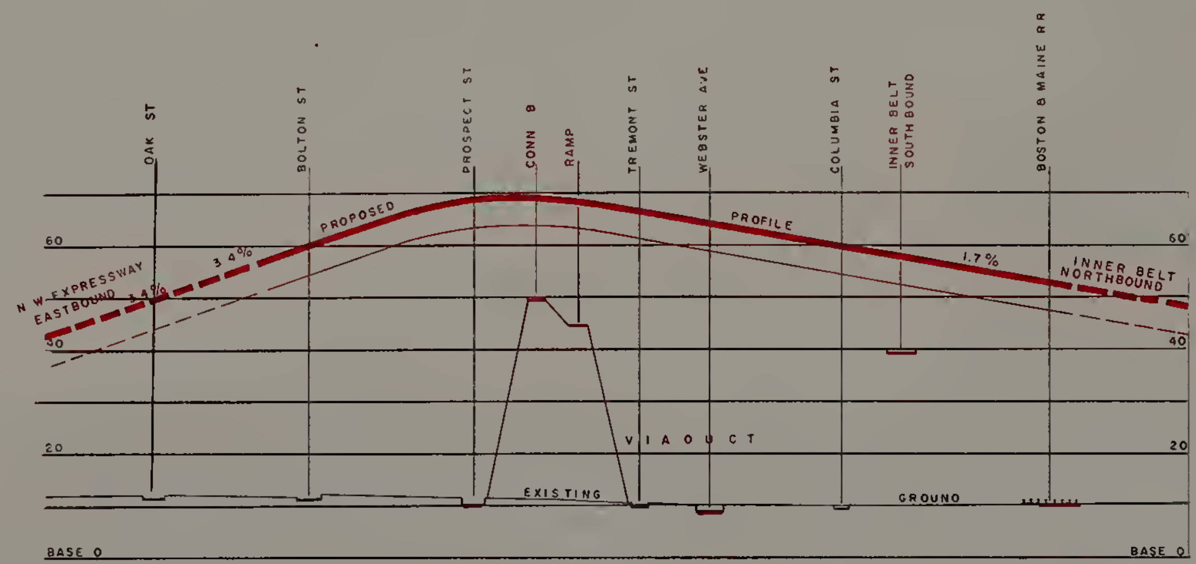
1975 TRAFFIC ASSIGNMENT



SHERMAN STREET TO CONCORD AVENUE
CAMBRIDGE-SOMERVILLE

HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

NORTHWEST EXPRESSWAY
RECOMMENDED LOCATION



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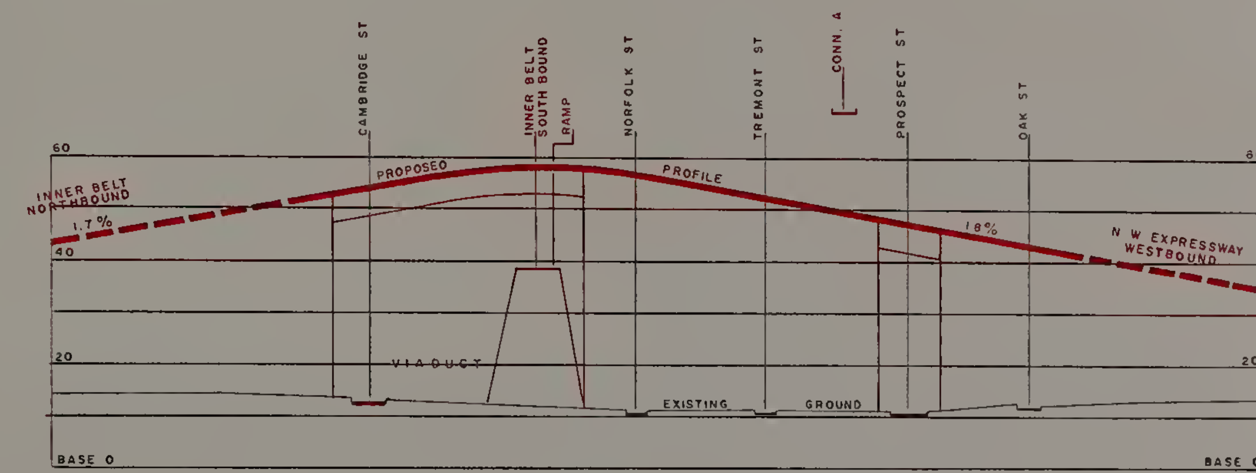

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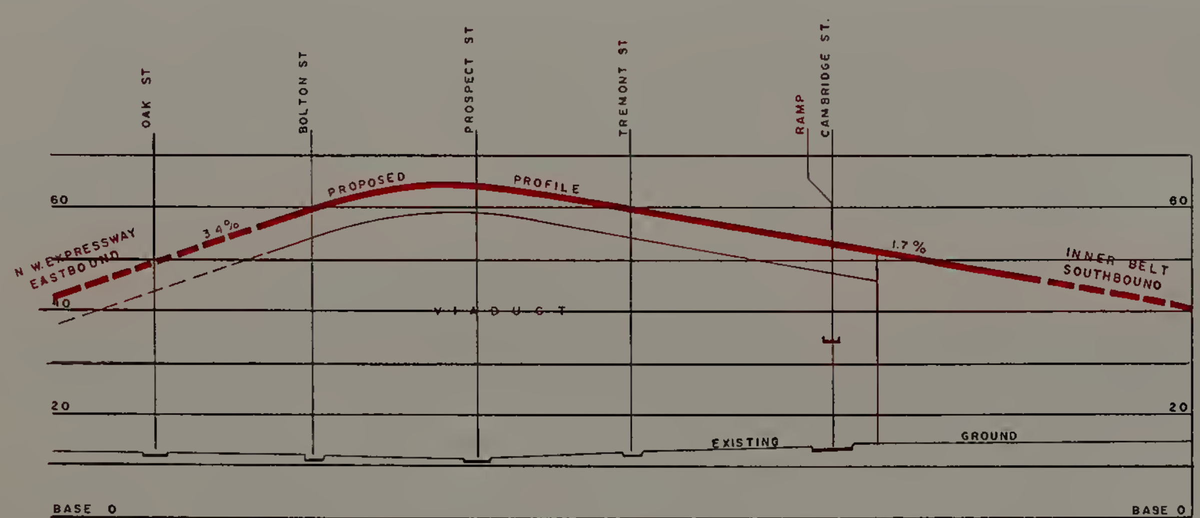

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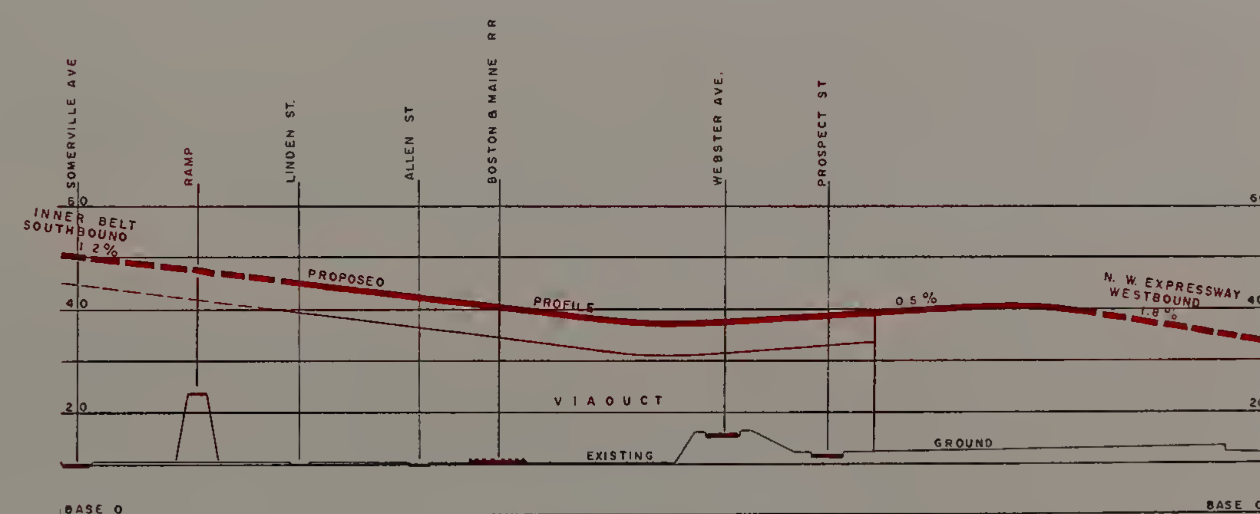


CONNECTOR D

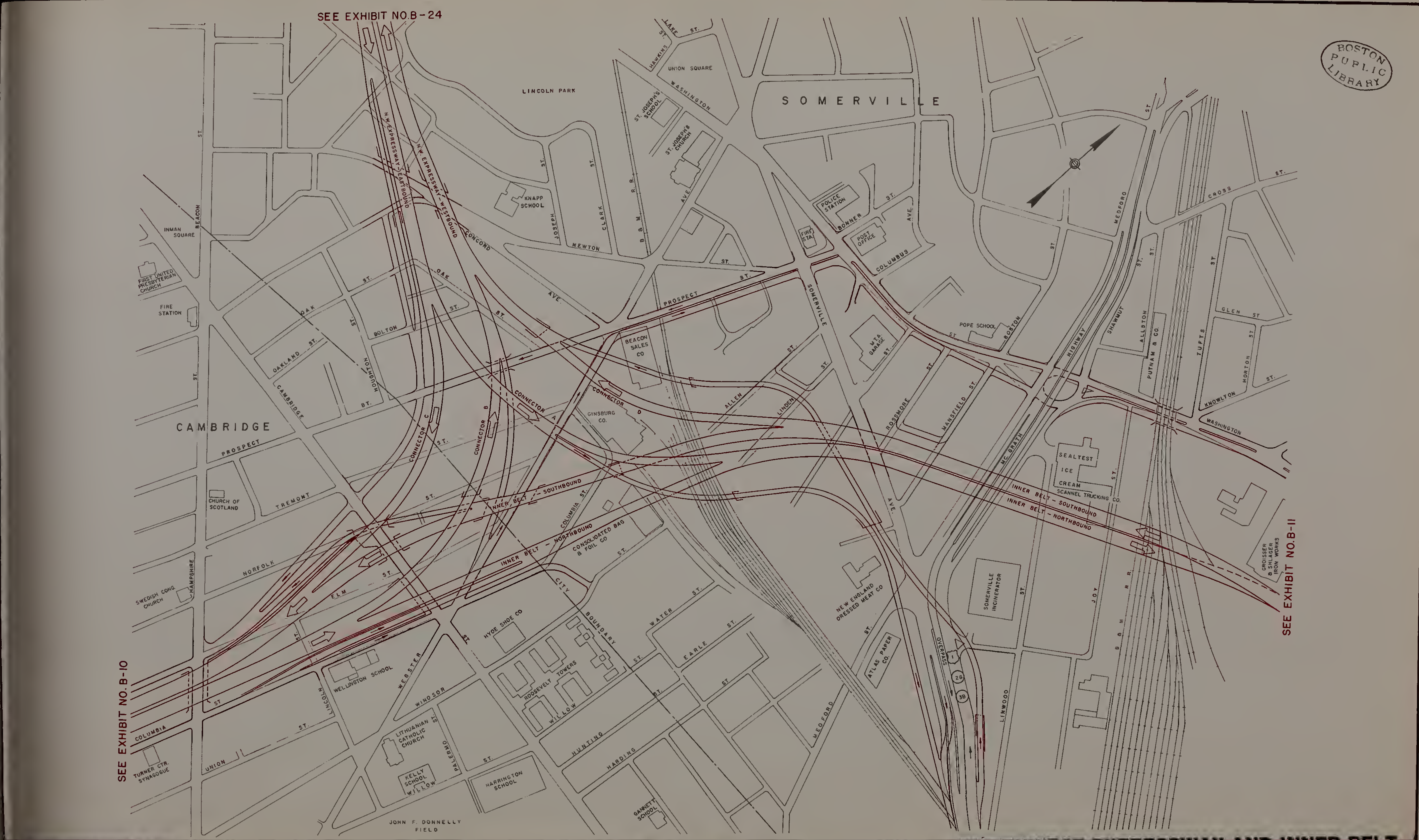
NORTHWEST EXPRESSWAY AND INNER BELT

RECOMMENDED LOCATION

HORIZONTAL SCALE 200 0 200 400
VERTICAL SCALE 20 0 20 40
SCALE IN FEET

INTERCHANGE PROFILES

CAMBRIDGE-SOMERVILLE



INTERCHANGE PLAN
CAMBRIDGE-SOMERVILLE

200 0 200 400
SCALE IN FEET

NORTHWEST EXPRESSWAY AND INNER BELT
RECOMMENDED LOCATION

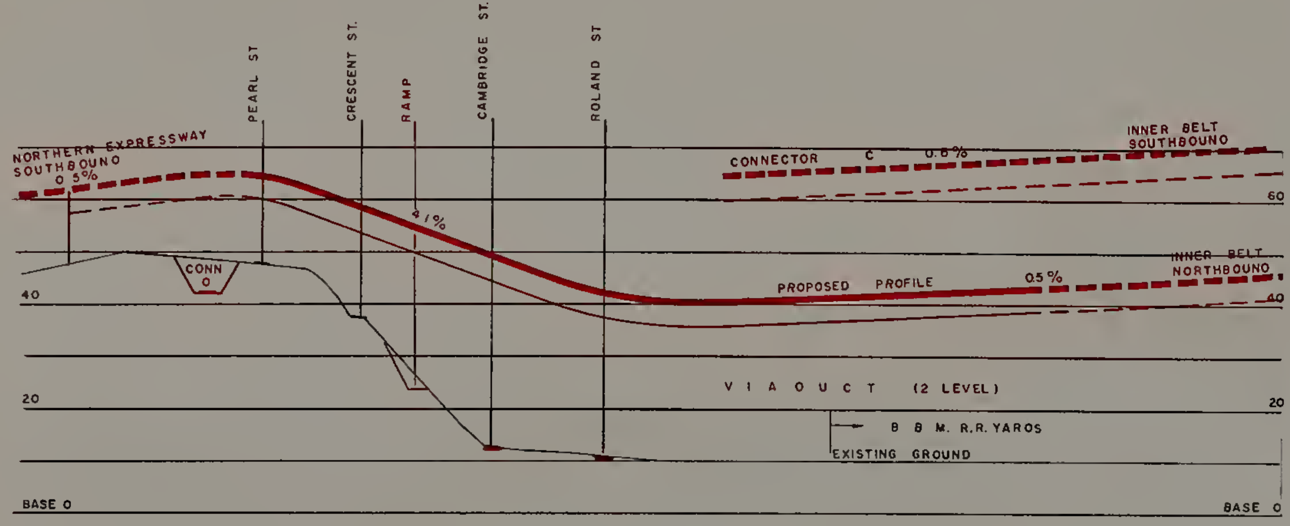
MYSTIC VALLEY PARKWAY TO BROADWAY

MEDFORD-SOMERVILLE

HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

NORTHERN EXPRESSWAY

RECOMMENDED LOCATION



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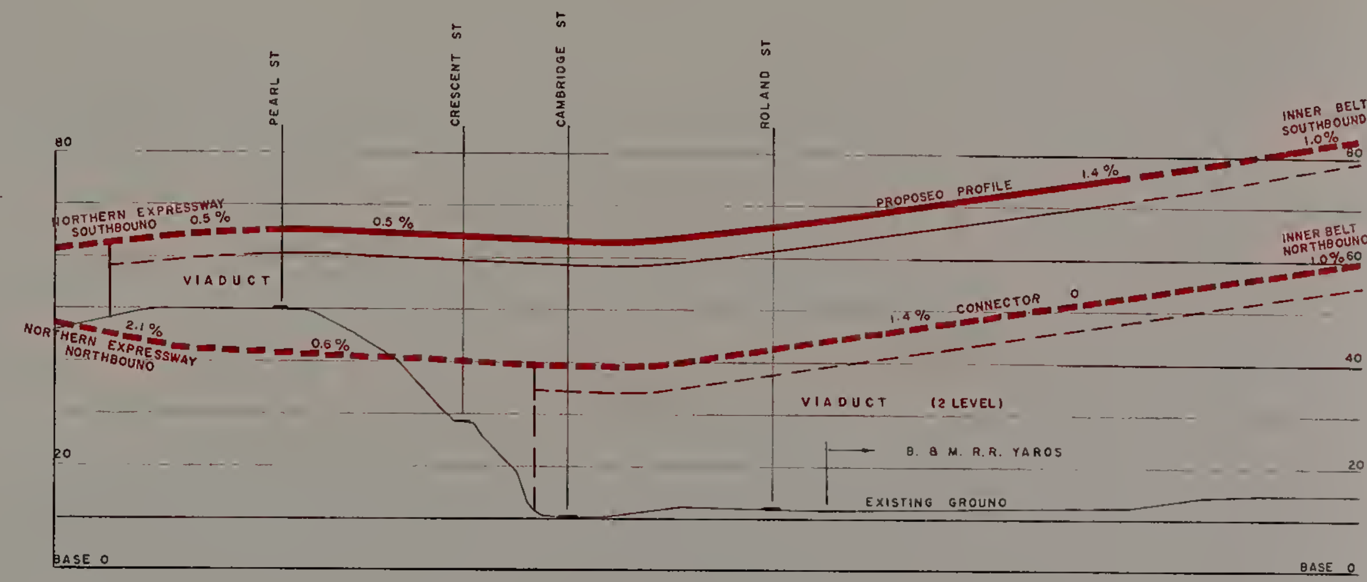

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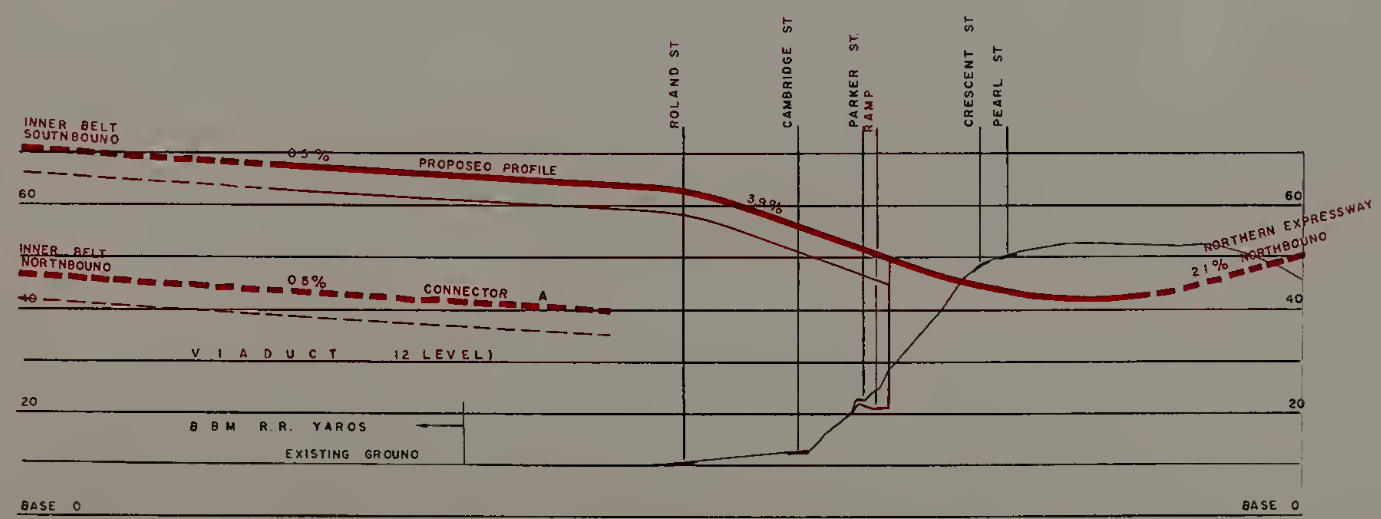

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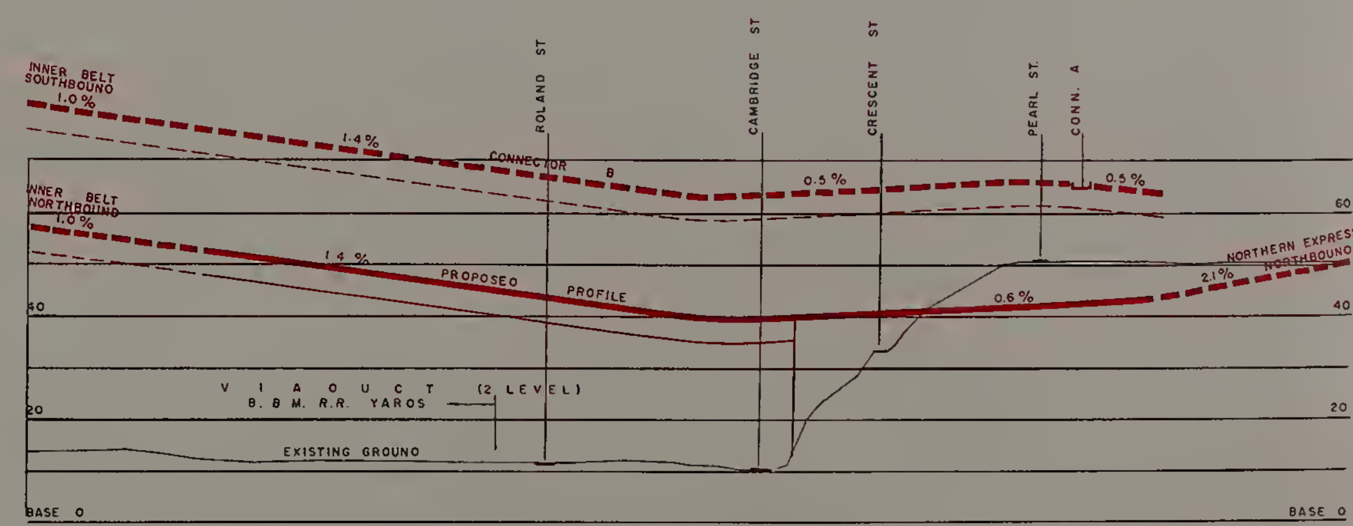


CONNECTOR D

NORTHERN EXPRESSWAY AND INNER BELT

RECOMMENDED LOCATION

HORIZONTAL SCALE 200 0 200 400
VERTICAL SCALE 20 0 20 40
SCALE IN FEET

INTERCHANGE PROFILES

SOMERVILLE-BOSTON

INTERCHANGE PLAN
SOMERVILLE-BOSTON

NORTHERN EXPRESSWAY AND INNER BELT
RECOMMENDED LOCATION

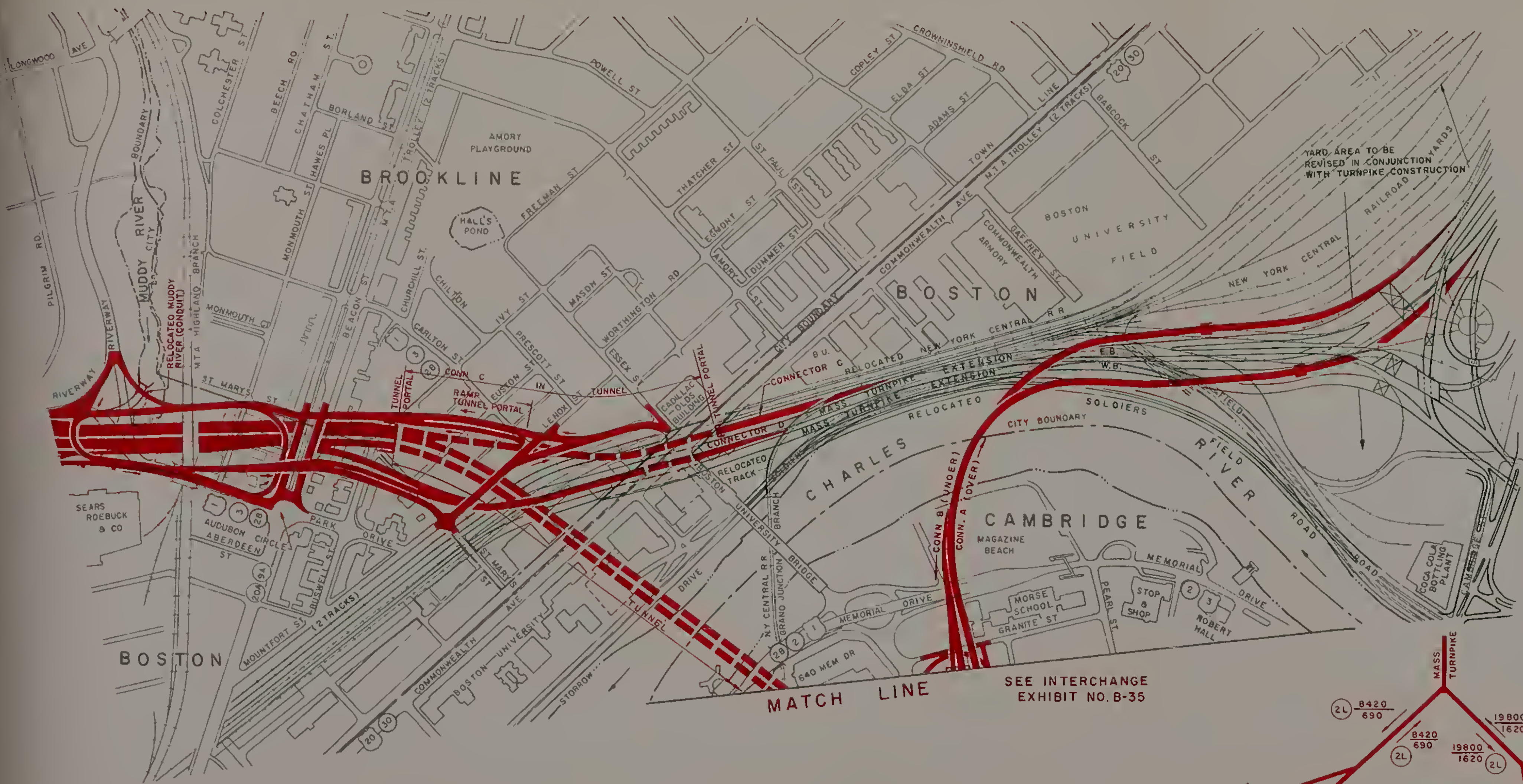
INNER BELT

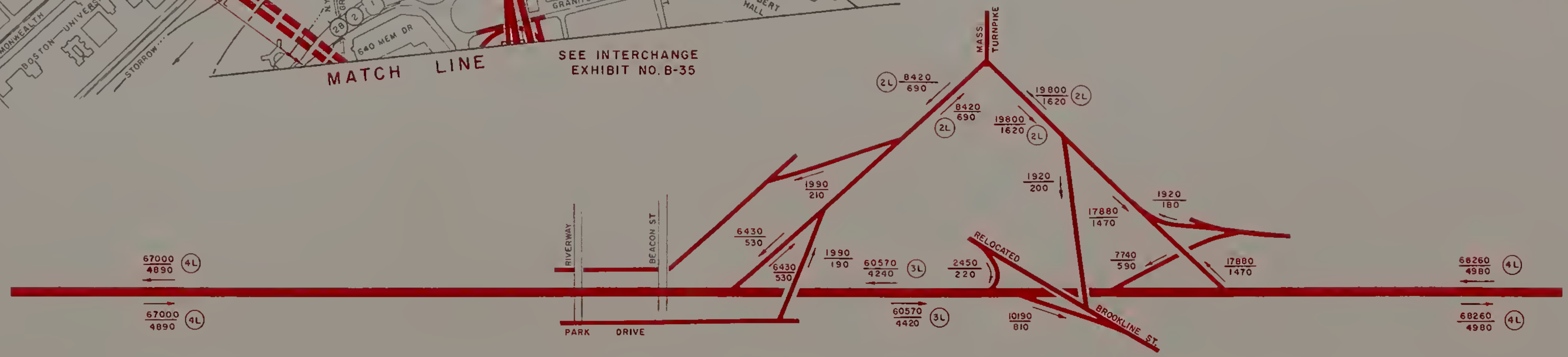
RECOMMENDED LOCATION-ALTERNATE DESIGN 1

HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

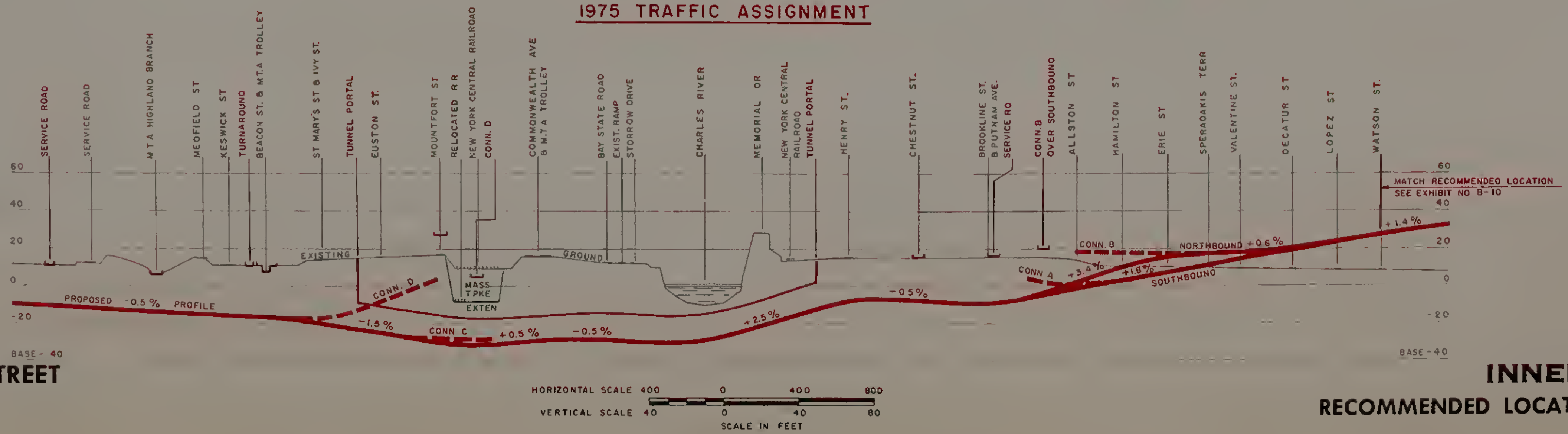
MASSACHUSETTS AVENUE TO BROOKLINE AVENUE

BOSTON



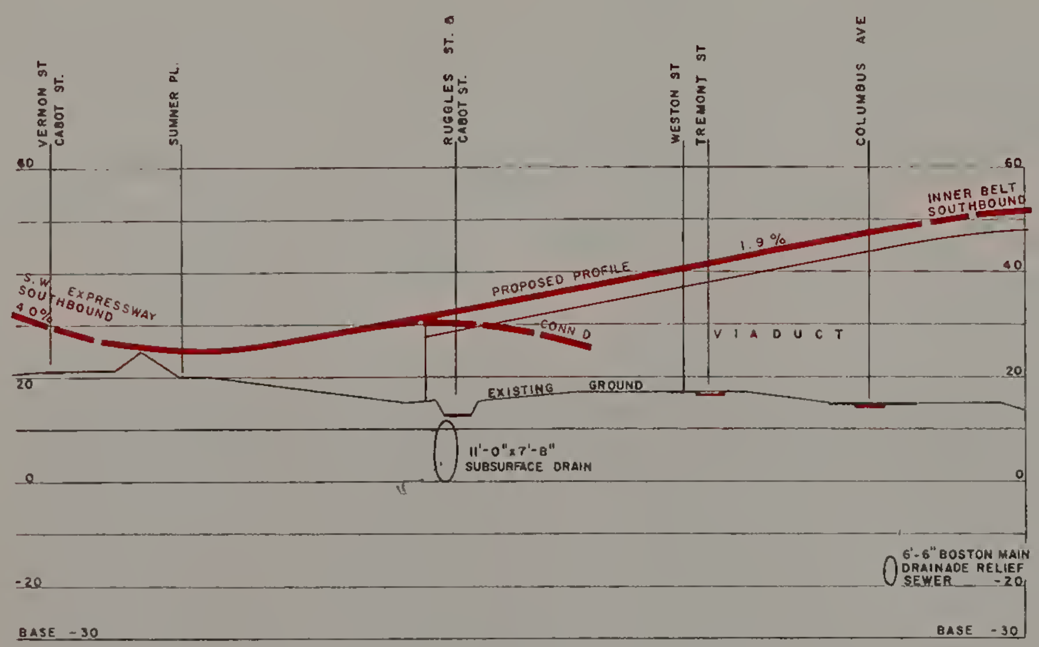


1975 TRAFFIC ASSIGNMENT



BROOKLINE AVENUE TO WATSON STREET
BOSTON-BROOKLINE-CAMBRIDGE

INNER BELT
RECOMMENDED LOCATION-ALTERNATE DESIGN I



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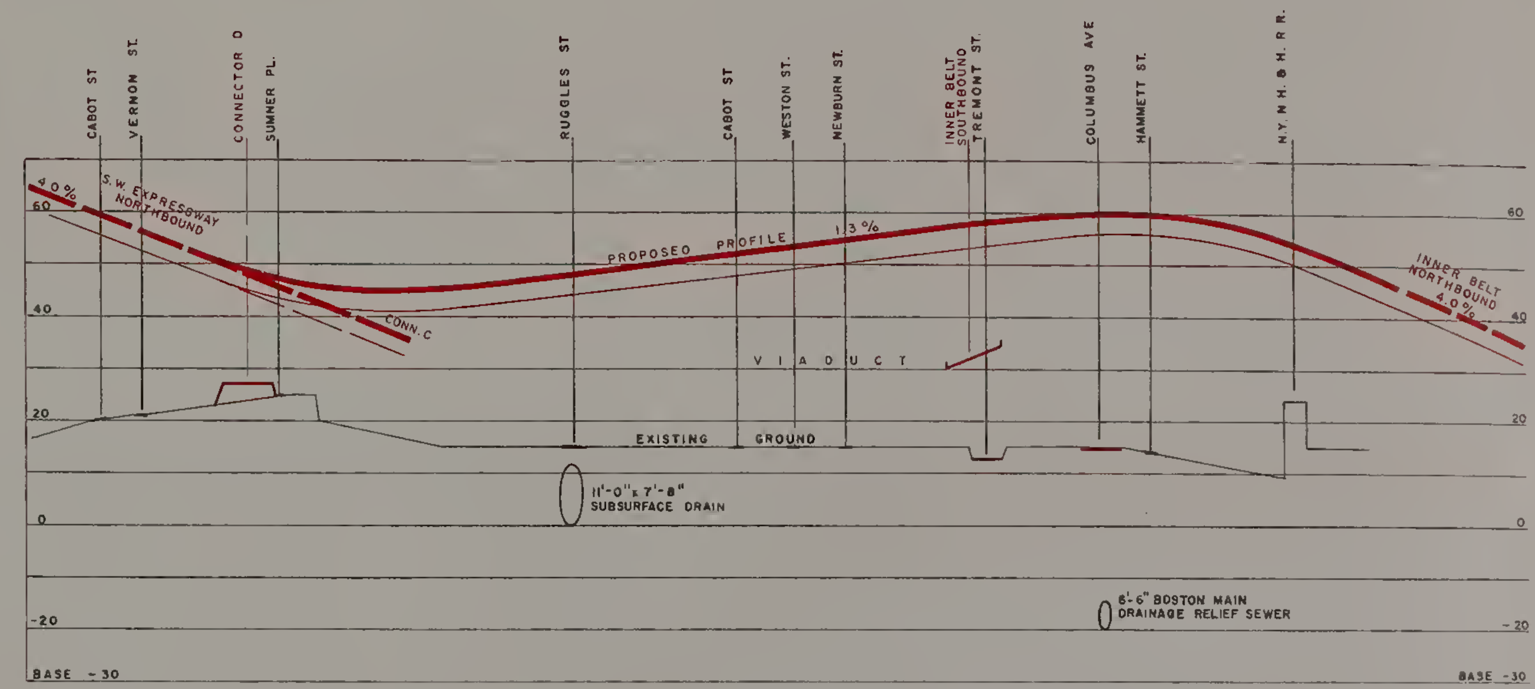

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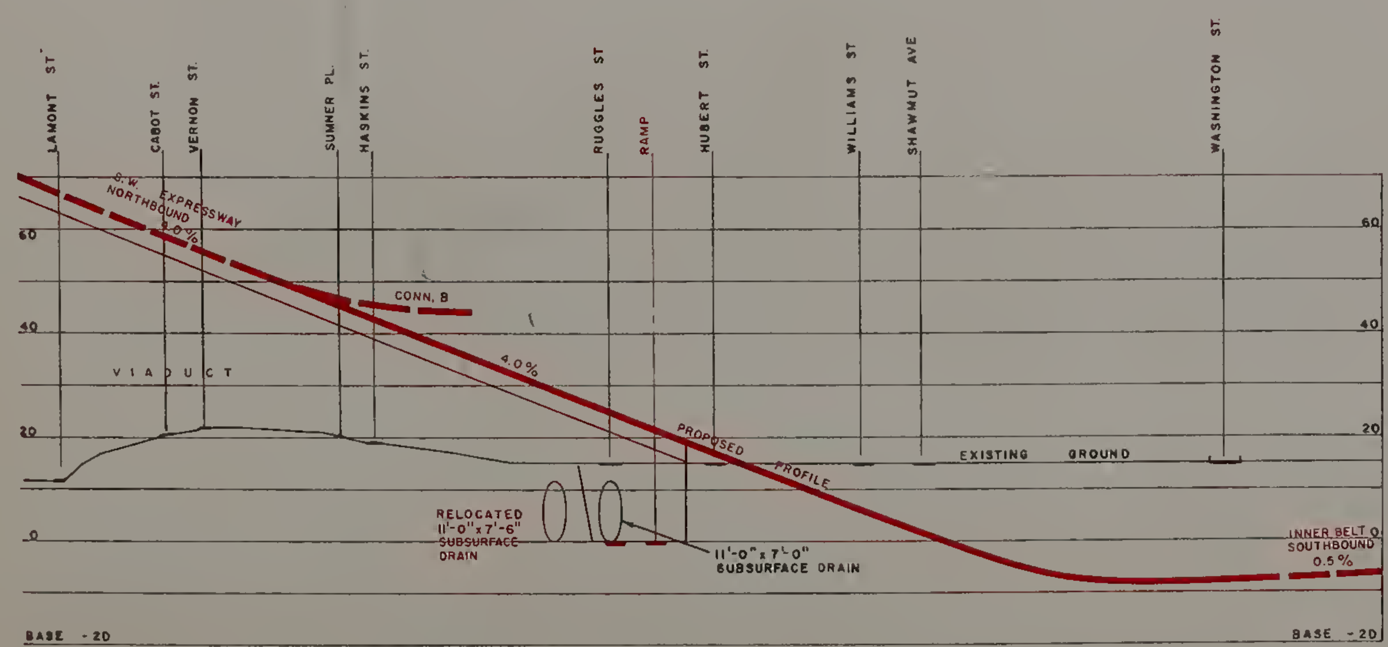

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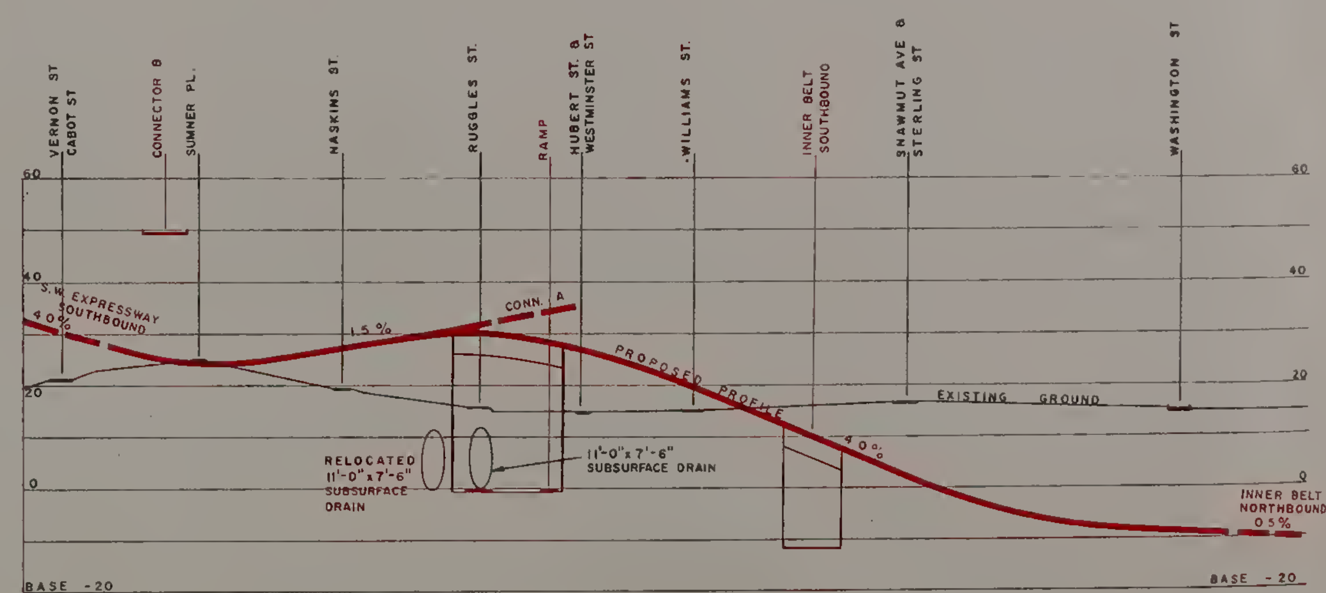


CONNECTOR D

SOUTHWEST EXPRESSWAY AND INNER BELT

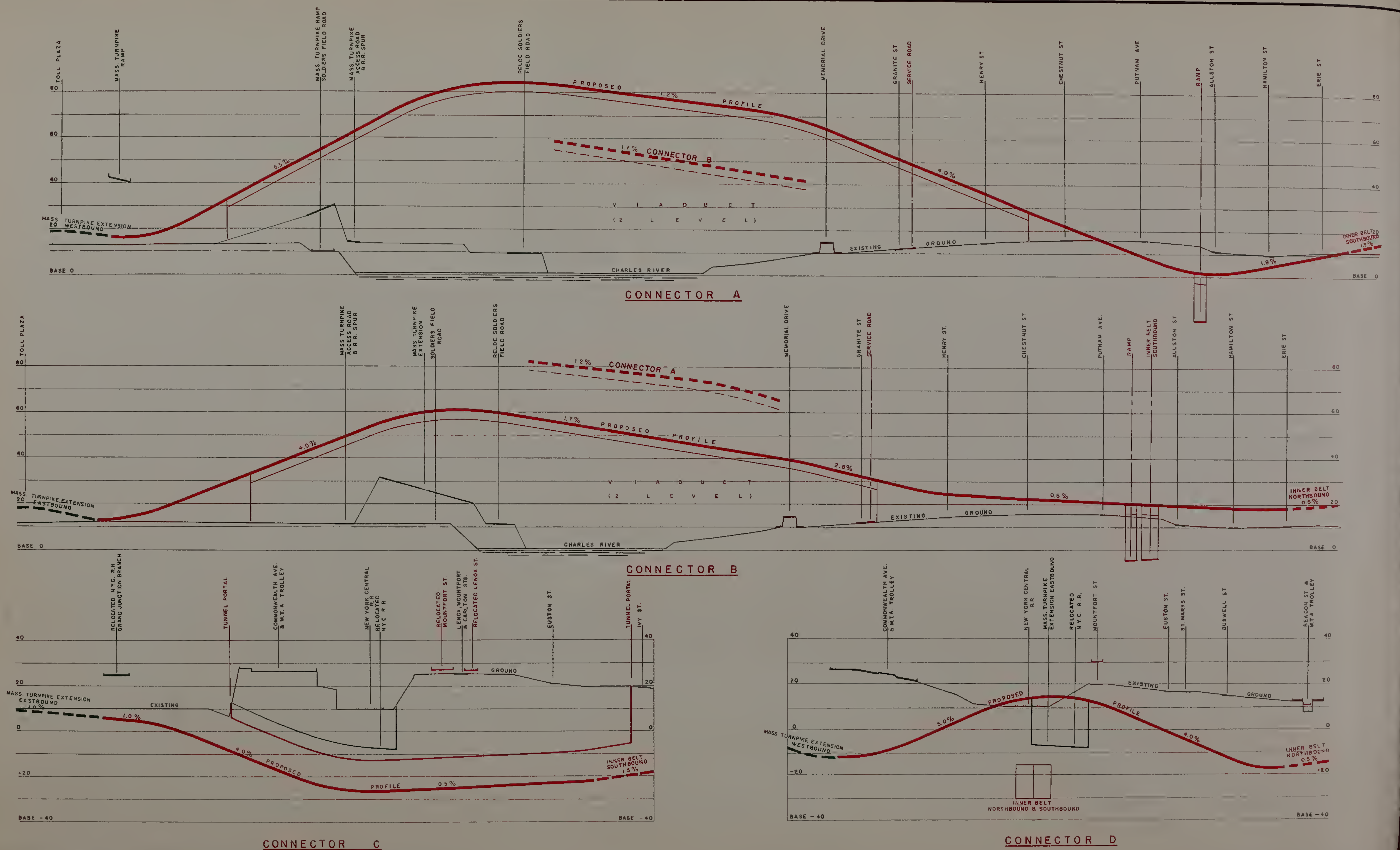
RECOMMENDED LOCATION-ALTERNATE DESIGN I

HORIZONTAL SCALE 200 0 200 400
VERTICAL SCALE 20 0 20 40
SCALE IN FEET

INTERCHANGE PROFILES
BOSTON

INTERCHANGE PLAN
BOSTON

SOUTHWEST EXPRESSWAY AND INNER BELT
RECOMMENDED LOCATION-ALTERNATE DESIGN I

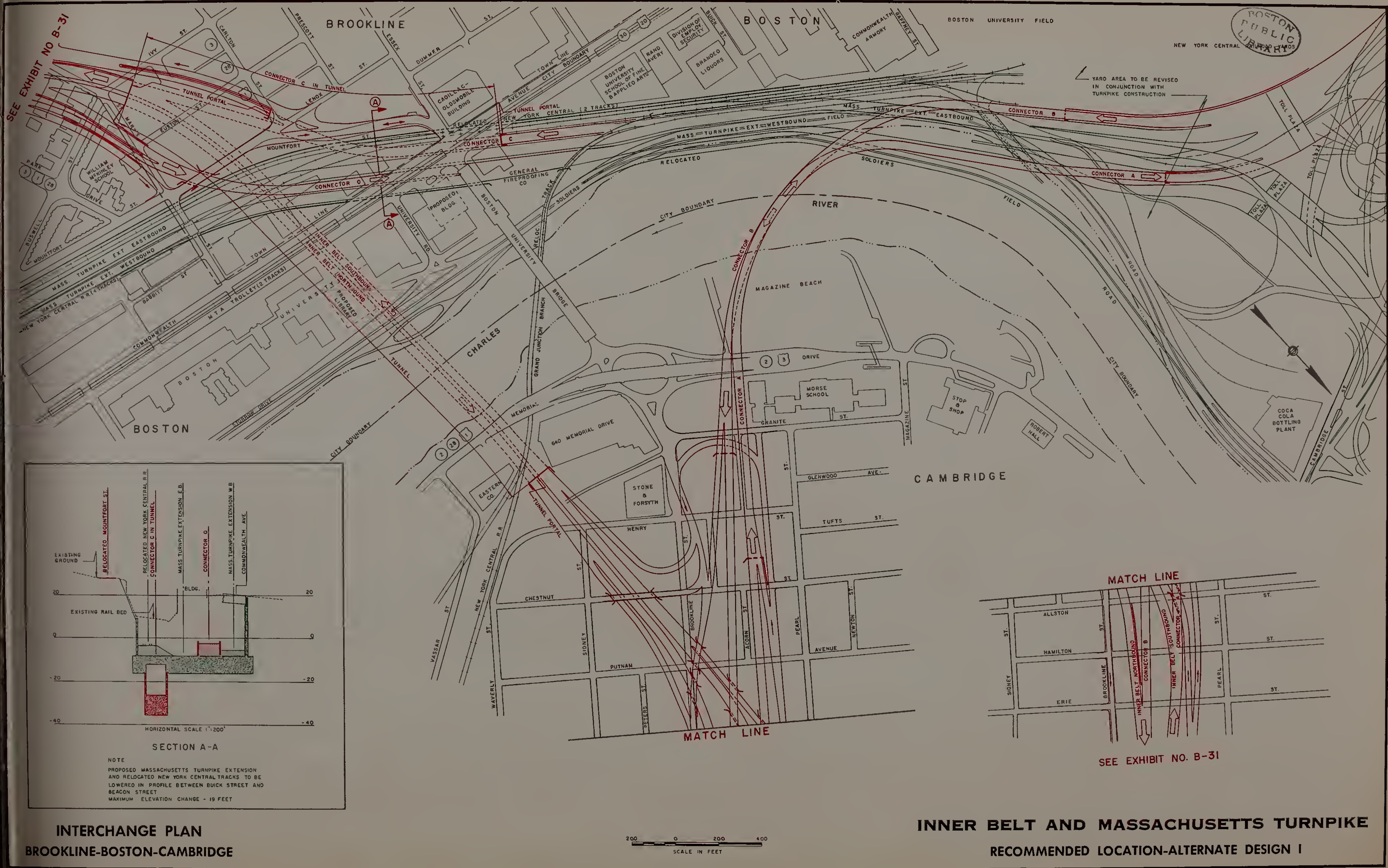


INNER BELT AND MASSACHUSETTS TURNPIKE

RECOMMENDED LOCATION-ALTERNATE DESIGN I

INTERCHANGE PROFILES

BROOKLINE-BOSTON-CAMBRIDGE



INTERCHANGE PLAN
BROOKLINE-BOSTON-CAMBRIDGE

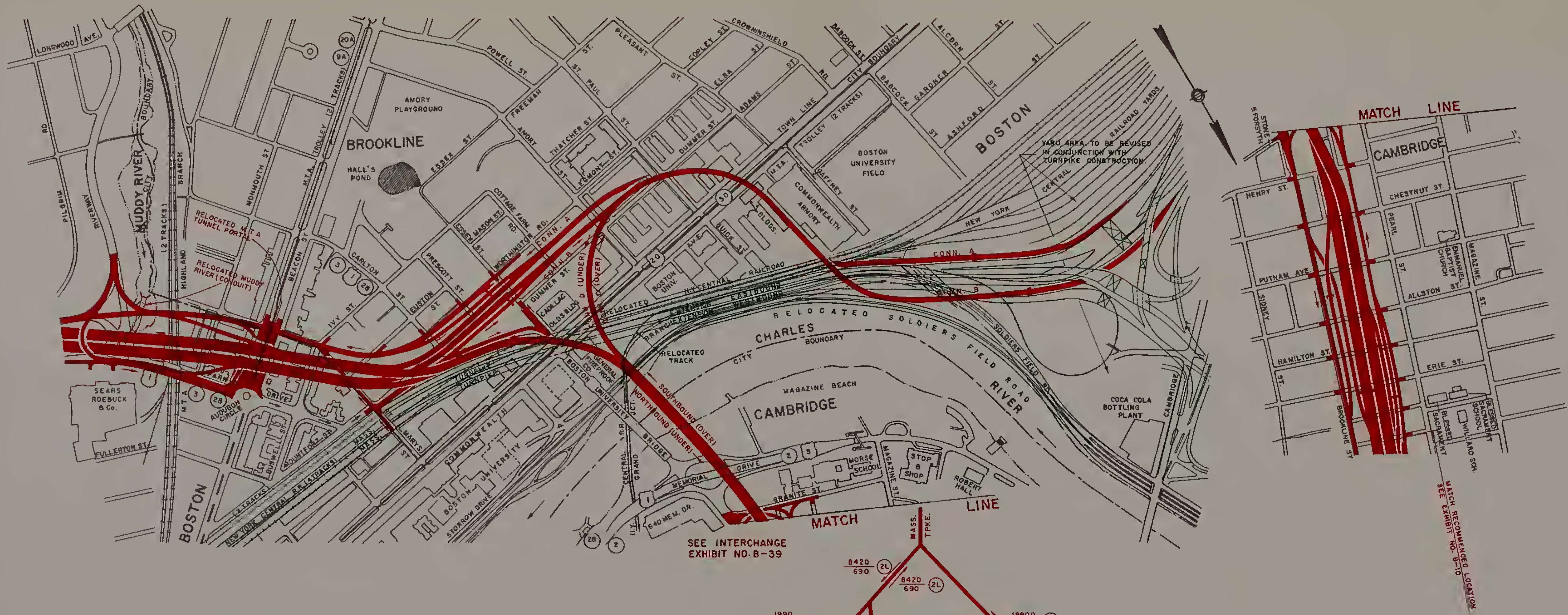
INNER BELT AND MASSACHUSETTS TURNPIKE
RECOMMENDED LOCATION-ALTERNATE DESIGN I

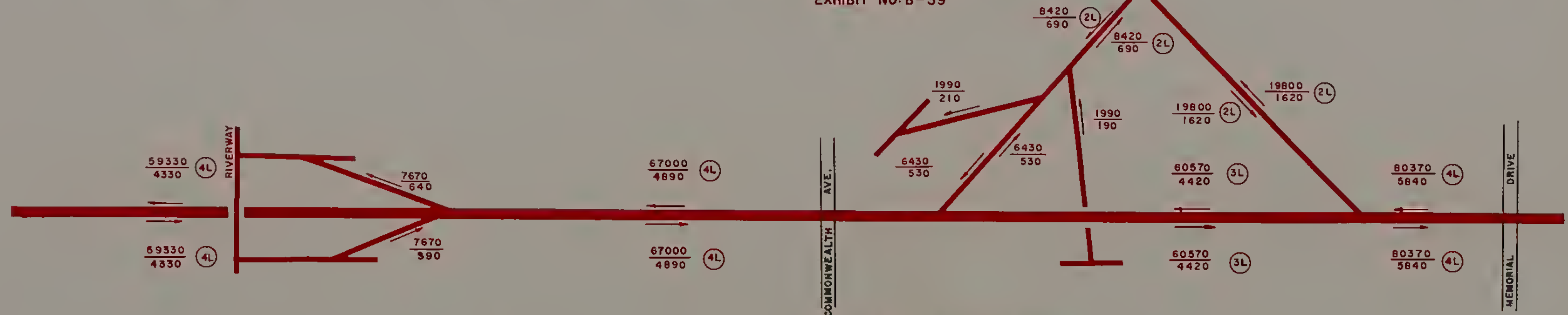
INNER BELT

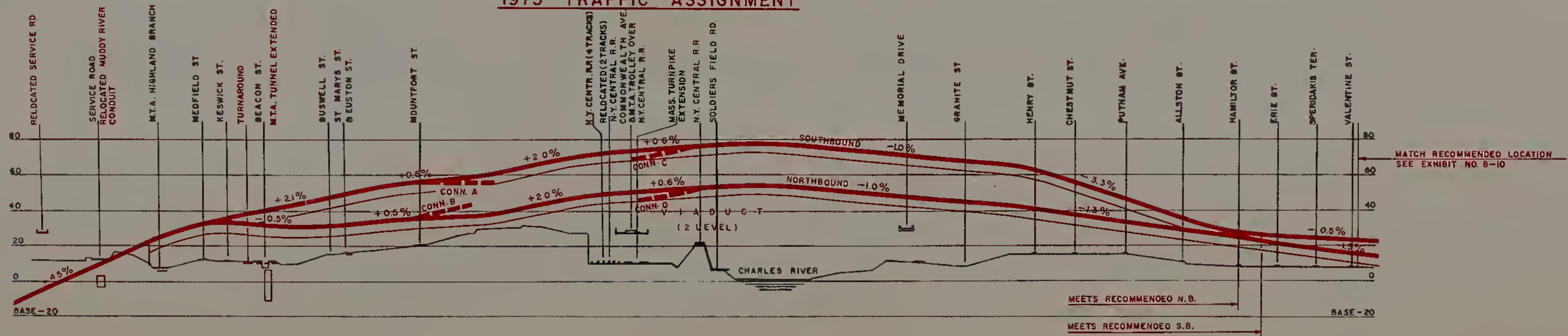
RECOMMENDED LOCATION-ALTERNATE DESIGN II

MASSACHUSETTS AVENUE TO BROOKLINE AVENUE

BOSTON



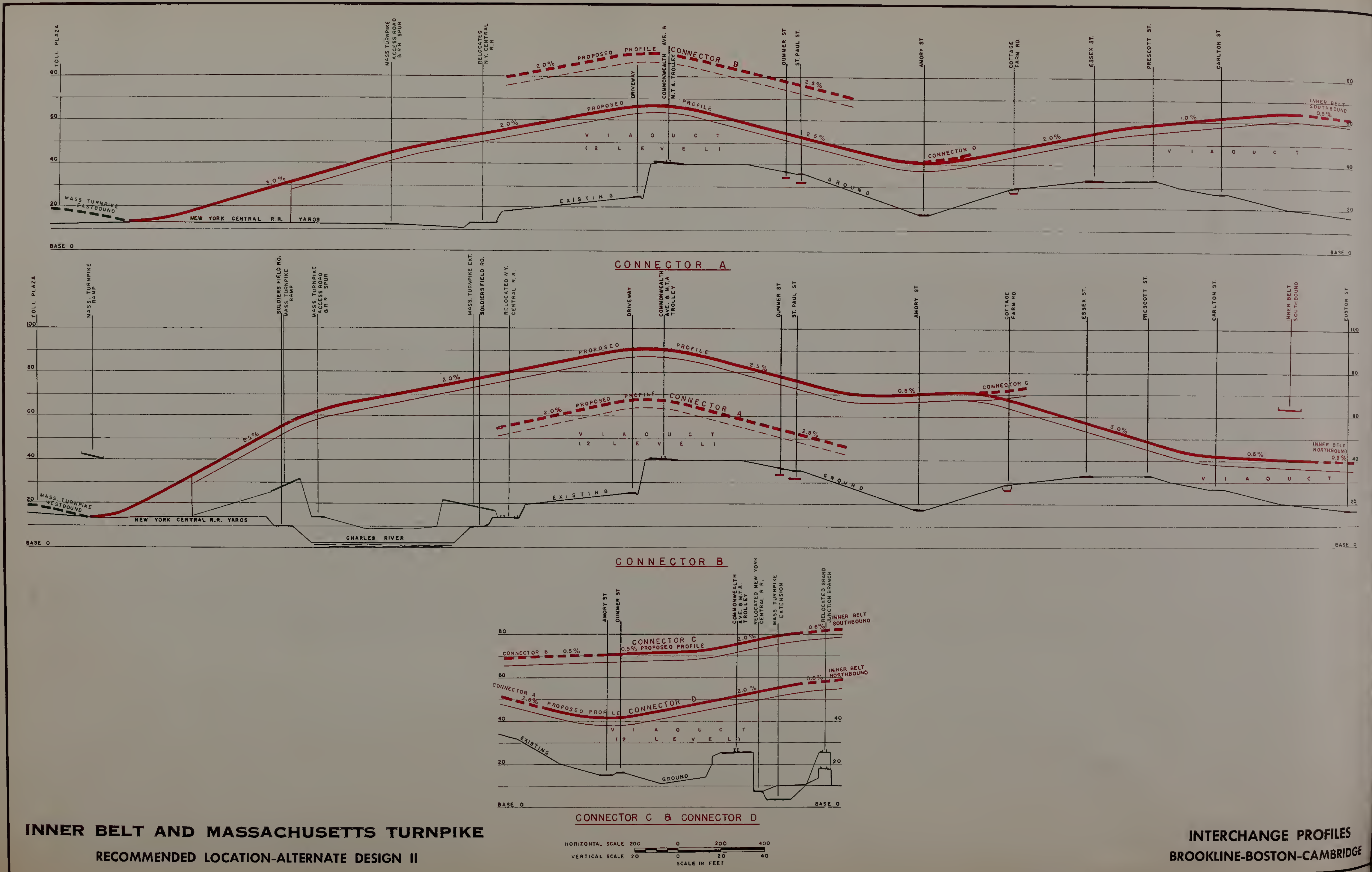




BROOKLINE AVENUE TO HAMILTON STREET
BOSTON-BROOKLINE-CAMBRIDGE

HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

INNER BELT
RECOMMENDED LOCATION-ALTERNATE DESIGN II



INNER BELT AND MASSACHUSETTS TURNPIKE

RECOMMENDED LOCATION-ALTERNATE DESIGN II

INTERCHANGE PROFILES

BROOKLINE-BOSTON-CAMBRIDGE

INTERCHANGE PLAN
BROOKLINE-BOSTON-CAMBRIDGE

INNER BELT AND MASSACHUSETTS TURNPIKE
RECOMMENDED LOCATION-ALTERNATE DESIGN II

EXHIBIT B-40
KEY MAP
ALTERNATE LOCATION

INNER BELT

ALTERNATE LOCATION

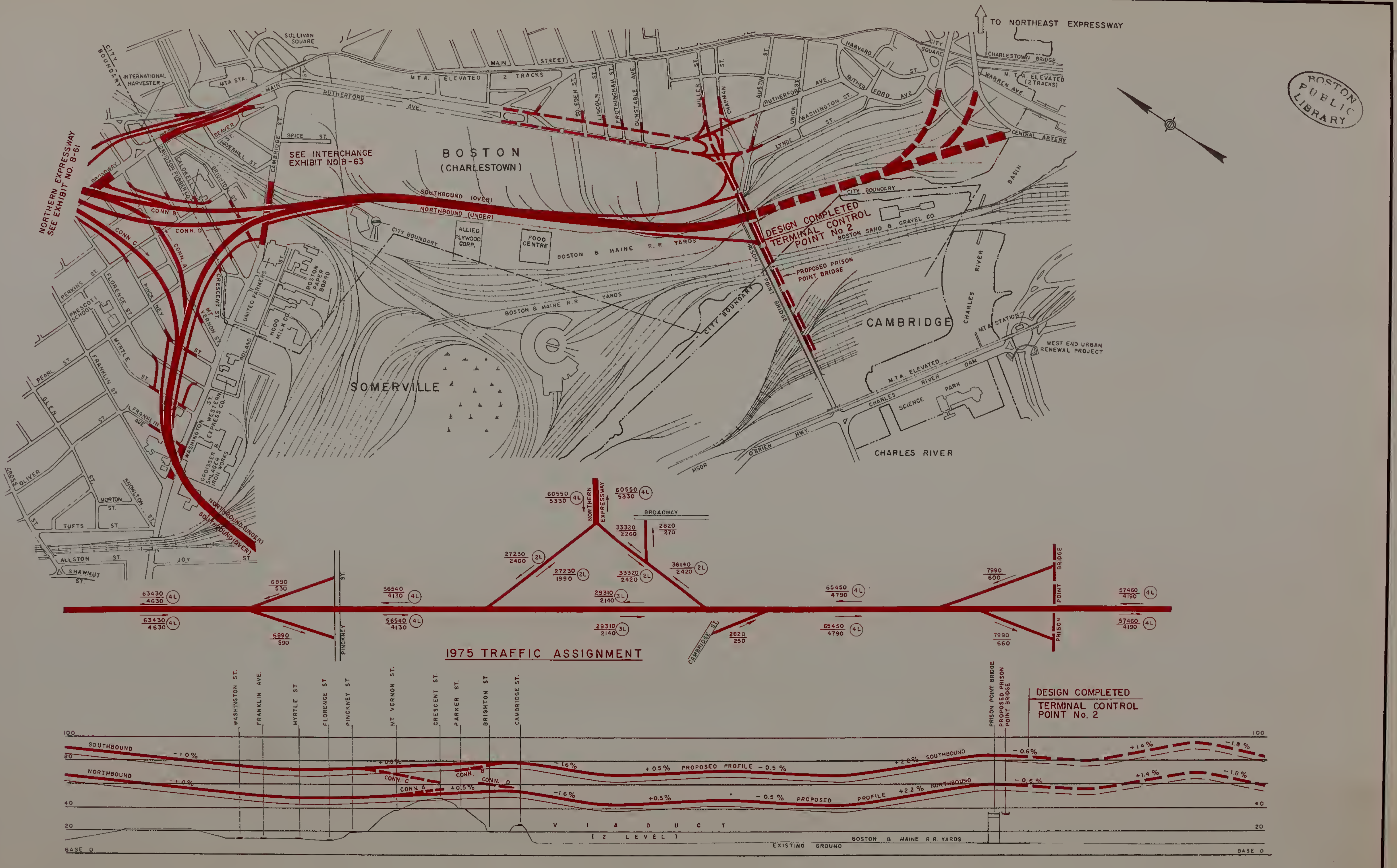
MASSACHUSETTS AVENUE TO ST. ALPHONSUS STREET

BOSTON

ST. ALPHONSUS STREET TO MEMORIAL DRIVE
BOSTON-BROOKLINE-CAMBRIDGE

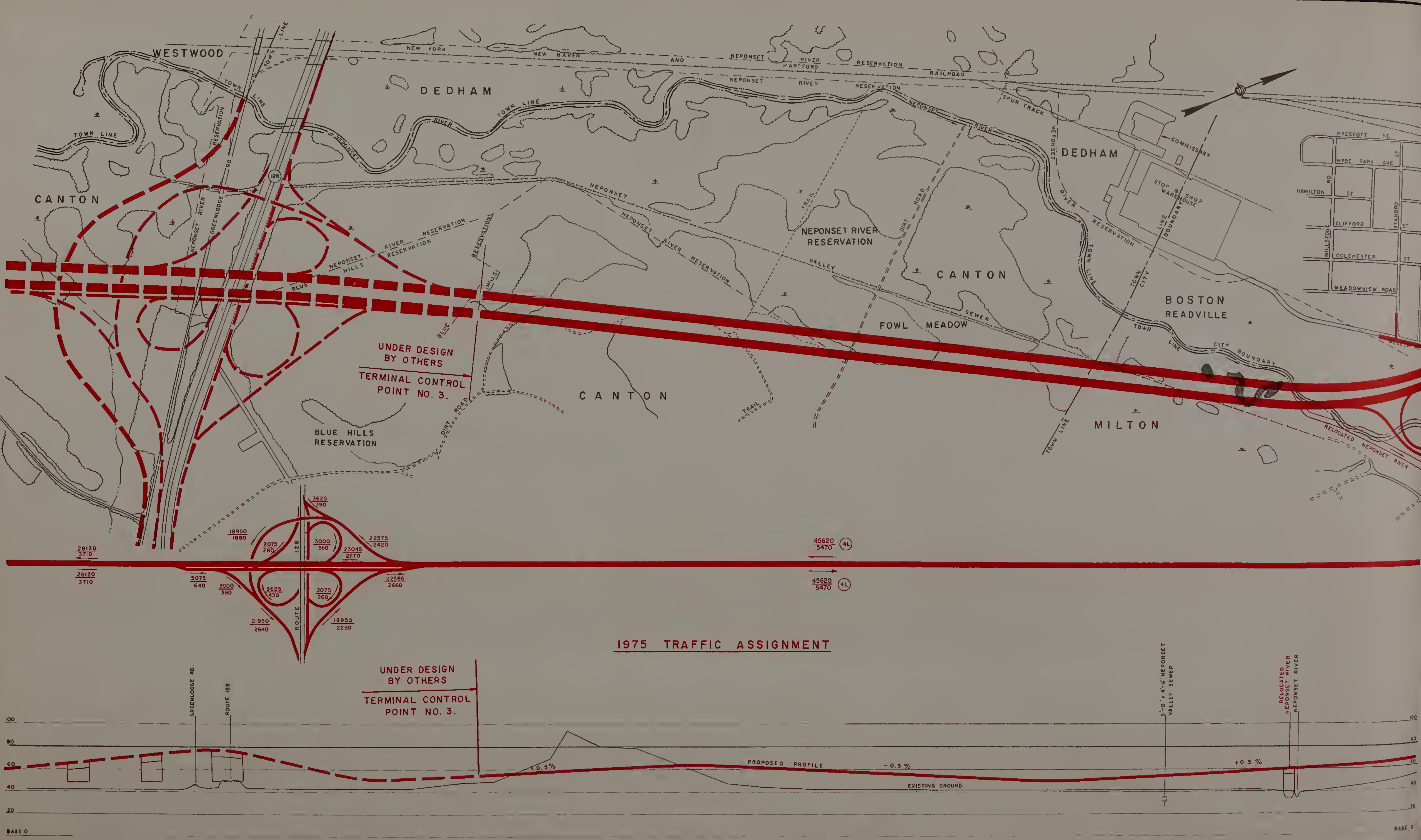
INNER BELT
ALTERNATE LOCATION

NORTHWEST EXPRESSWAY SEE EXHIBIT NO. B-58
SEE INTERCHANGE EXHIBIT NO. B-60
BOSTON
CHARLES RIVER
CAMBRIDGE
SOMERVILLE
TECHNOLOGY SQUARE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
RELOC. R.R. SIDING & SWITCHING TRACKS
RELOCATED GRAND JUNCTION BRANCH N.Y. CENTRAL RR (TWO TRACKS) UNDER INNER BELT
INNER BELT SOUTHBOUND (OVER)
INNER BELT NORTHBOUND (UNDER)
1975 TRAFFIC ASSIGNMENT
PROPOSED PROFILE
SOUTHBOUND
NORTHBOUND
VIADUCT (2 LEVEL)
EXISTING GROUND
HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET
INNER BELT
ALTERNATE LOCATION
MEMORIAL DRIVE TO McGRATH HIGHWAY
CAMBRIDGE-SOMERVILLE



McGRATH HIGHWAY TO PRISON POINT BRIDGE
SOMERVILLE-BOSTON

INNER BELT
ALTERNATE LOCATION



SOUTHWEST EXPRESSWAY

ALTERNATE LOCATION

ROUTE 128 TO NEPONSET VALLEY PARKWAY

CANTON-MILTON-BOSTON

HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

NEPONSET VALLEY PARKWAY TO THATCHER STREET
BOSTON

SOUTHWEST EXPRESSWAY
ALTERNATE LOCATION

EXHIBIT B-47

SOUTHWEST EXPRESSWAY

ALTERNATE LOCATION

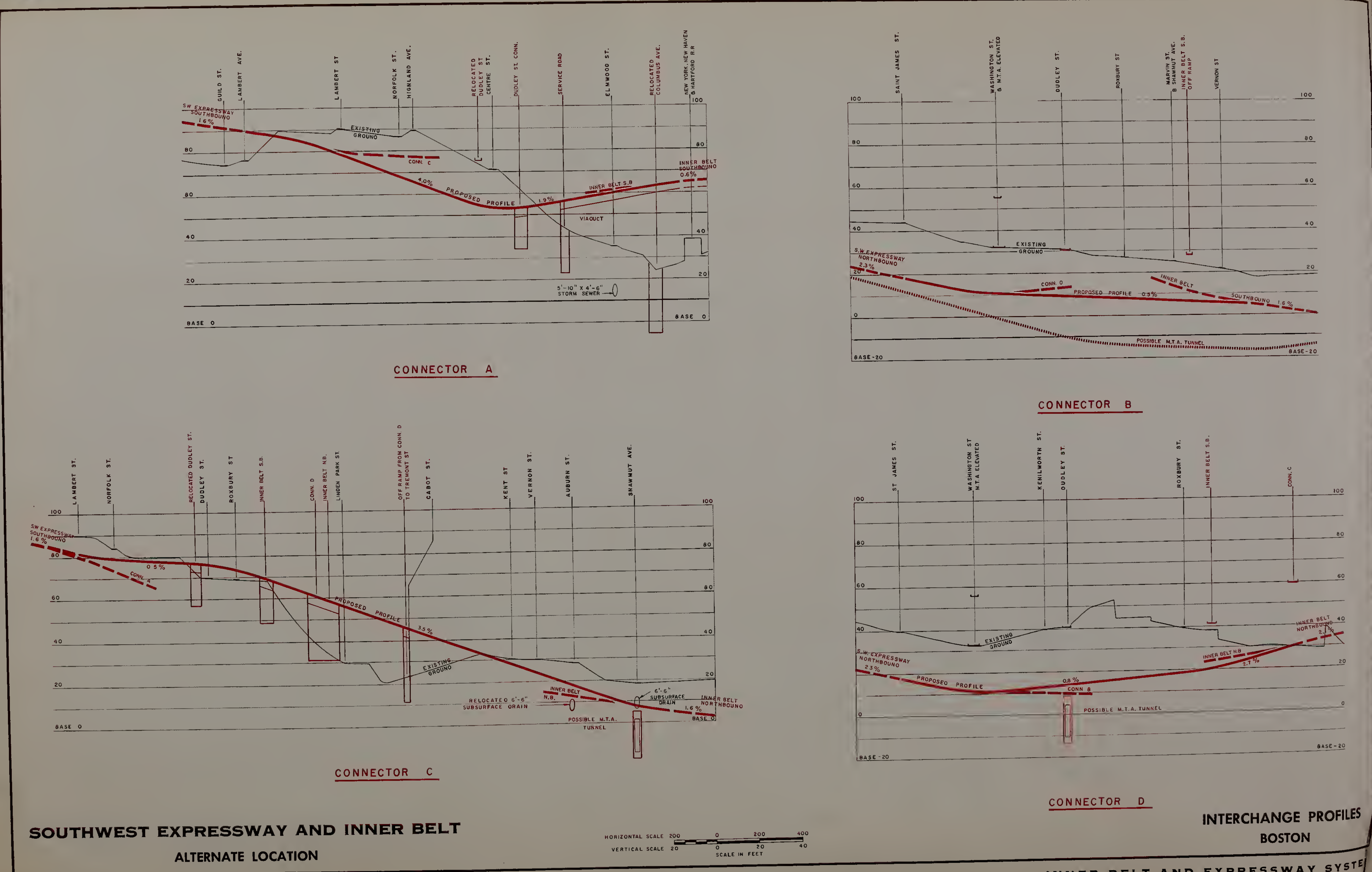
HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

THATCHER STREET TO THE ARBORWAY

BOSTON

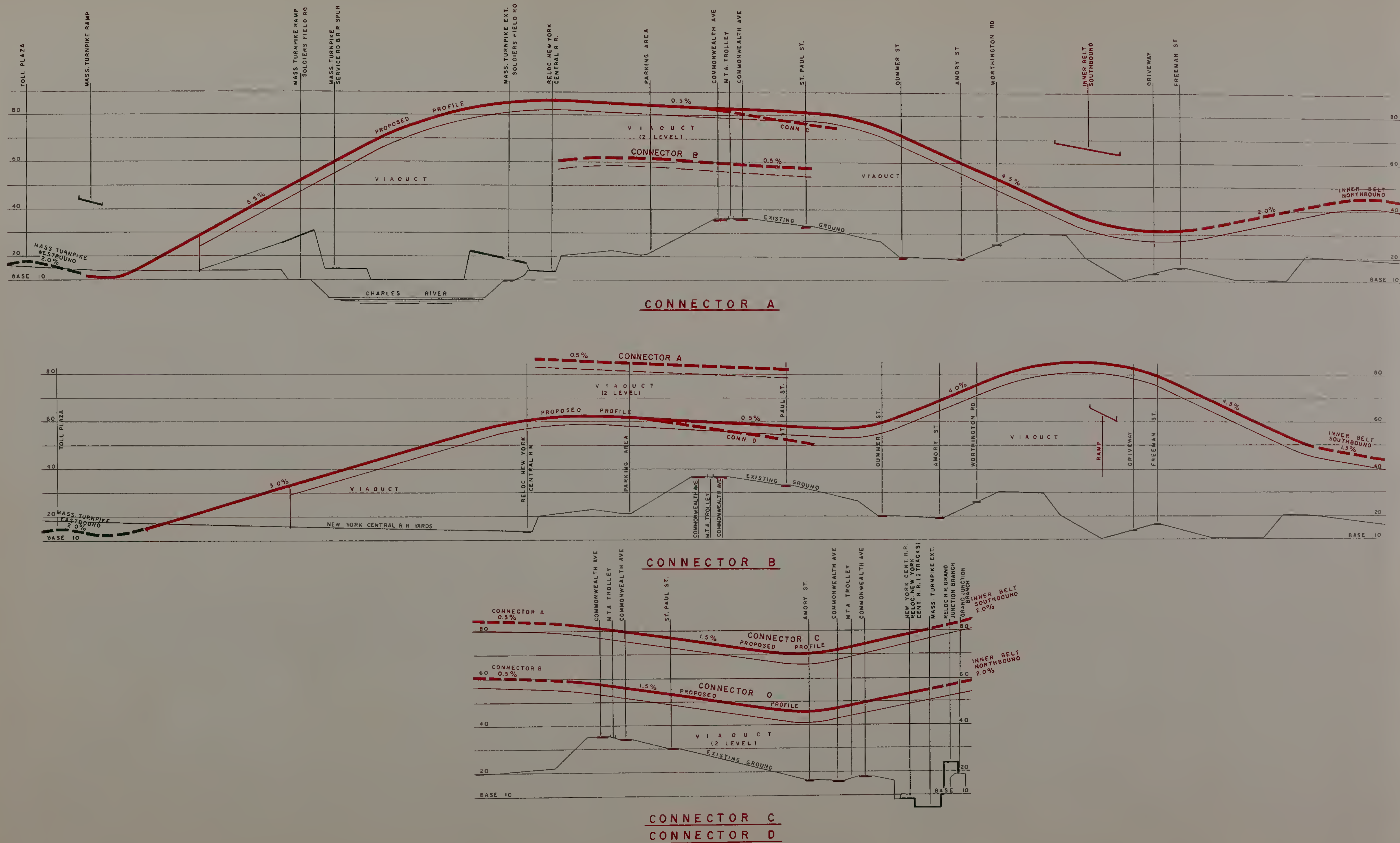
THE ARBORWAY TO HULBERT STREET
BOSTON

SOUTHWEST EXPRESSWAY
ALTERNATE LOCATION


GUILD ST.
LAMBERT AVE.
LAMBERT ST
NORFOLK ST.
HIGHLAND AVE.
RELOCATED DUDLEY ST CENTRE ST.
DUDLEY ST. CONN.
SERVICE ROAD
ELMWOOD ST.
RELOCATED COLUMBUS AVE.
NEW YORK, NEW HAVEN & HARTFORD R.R
SW EXPRESSWAY SOUTHBOUND 1.6%
EXISTING GROUND
CONN. C
4.0%
PROPOSED PROFILE
1.9%
INNER BELT S.B.
INNER BELT SOUTHBOUND 0.6%
VIADUCT
5'-10" X 4'-6" STORM SEWER
BASE 0
CONNECTOR A
SAINT JAMES ST.
WASHINGTON ST. & M.T.A. ELEVATED
DUDLEY ST.
ROXBURY ST
MARVIN ST. & SHAWMUT AVE.
INNER BELT S.B. OFF RAMP
VERNON ST
EXISTING GROUND
S.W. EXPRESSWAY NORTHBOUND 2.3%
CONN. D
PROPOSED PROFILE 0.5%
INNER BELT SOUTHBOUND 1.6%
POSSIBLE M.T.A. TUNNEL
BASE -20
CONNECTOR B
LAMBERT ST.
NORFOLK ST.
RELOCATED DUDLEY ST.
DUDLEY ST.
ROXBURY ST
INNER BELT S.B.
CONN. D
INNER BELT N.B.
LINDEN PARK ST
OFF RAMP FROM CONN D TO TREMONT ST
CABOT ST.
KENT ST
VERNON ST.
AUBURN ST.
SHAWMUT AVE.
SW EXPRESSWAY SOUTHBOUND 1.6%
0.5%
CONN. A
PROPOSED PROFILE
3.5%
EXISTING GROUND
INNER BELT N.B.
RELOCATED 6'-6" SUBSURFACE DRAIN
6'-6" SUBSURFACE DRAIN
1.6%
INNER BELT NORTHBOUND
POSSIBLE M.T.A. TUNNEL
BASE 0
CONNECTOR C
ST JAMES ST.
WASHINGTON ST M.T.A. ELEVATED
KENILWORTH ST.
DUDLEY ST.
ROXBURY ST.
INNER BELT S.B.
CONN. C
EXISTING GROUND
S.W. EXPRESSWAY NORTHBOUND 2.3%
PROPOSED PROFILE
0.8%
CONN. B
POSSIBLE M.T.A. TUNNEL
INNER BELT N.B.
2.7%
INNER BELT NORTHBOUND
BASE -20
CONNECTOR D
SOUTHWEST EXPRESSWAY AND INNER BELT
ALTERNATE LOCATION
HORIZONTAL SCALE 200 0 200 400
VERTICAL SCALE 20 0 20 40
SCALE IN FEET
INTERCHANGE PROFILES
BOSTON

INTERCHANGE PLAN
BOSTON

SOUTHWEST EXPRESSWAY AND INNER BELT
ALTERNATE LOCATION



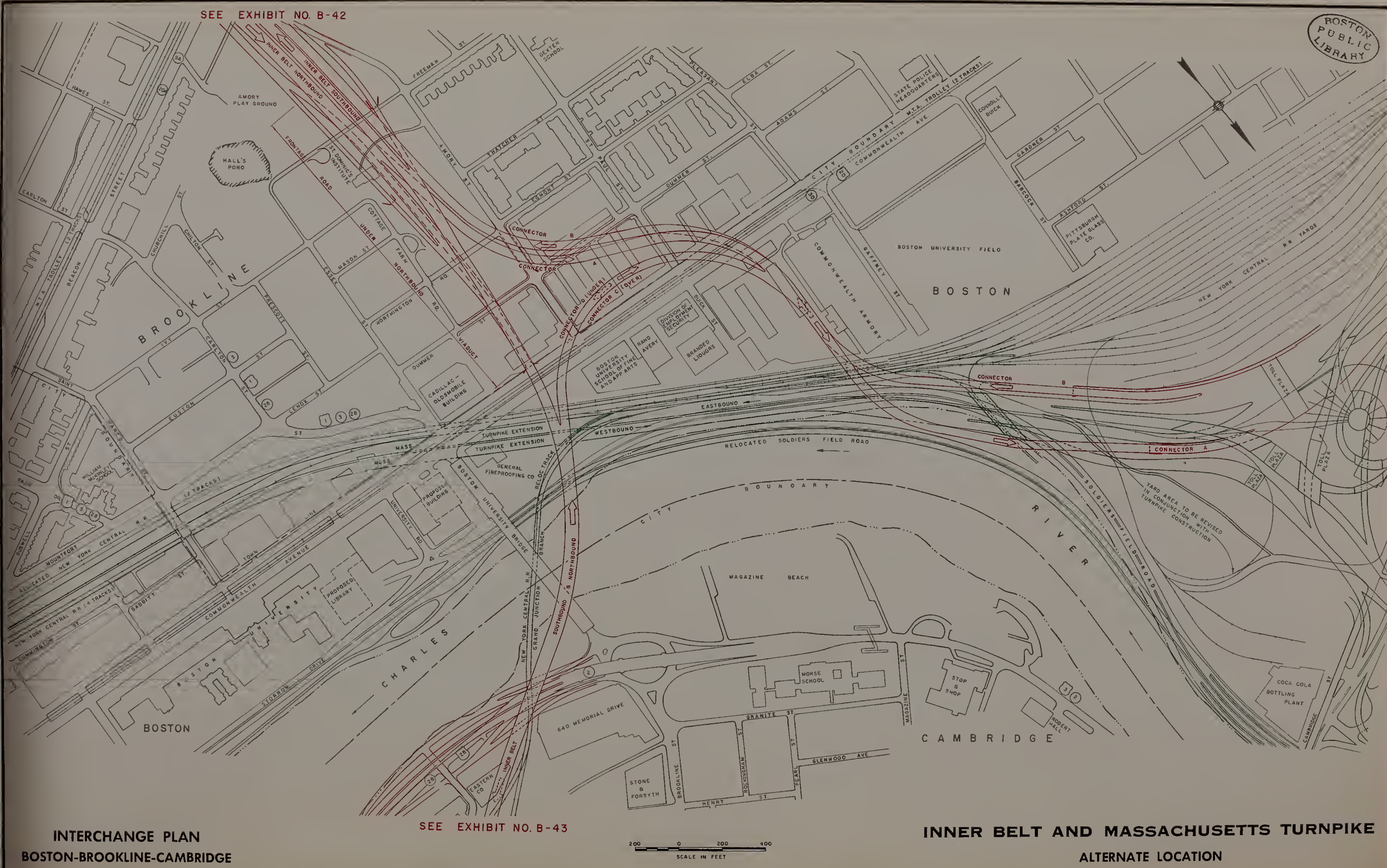
INNER BELT AND MASSACHUSETTS TURNPIKE

ALTERNATE LOCATION

HORIZONTAL SCALE 200 0 200 400
VERTICAL SCALE 20 0 20 40
SCALE IN FEET

INTERCHANGE PROFILES

BOSTON-BROOKLINE-CAMBRIDGE



INTERCHANGE PLAN
BOSTON-BROOKLINE-CAMBRIDGE

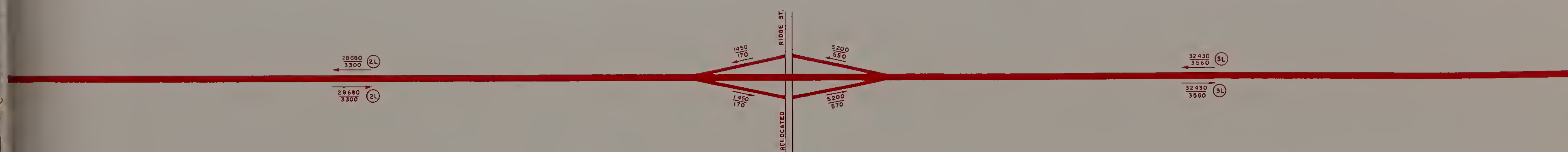
INNER BELT AND MASSACHUSETTS TURNPIKE
ALTERNATE LOCATION

ROUTE 3 EXPRESSWAY

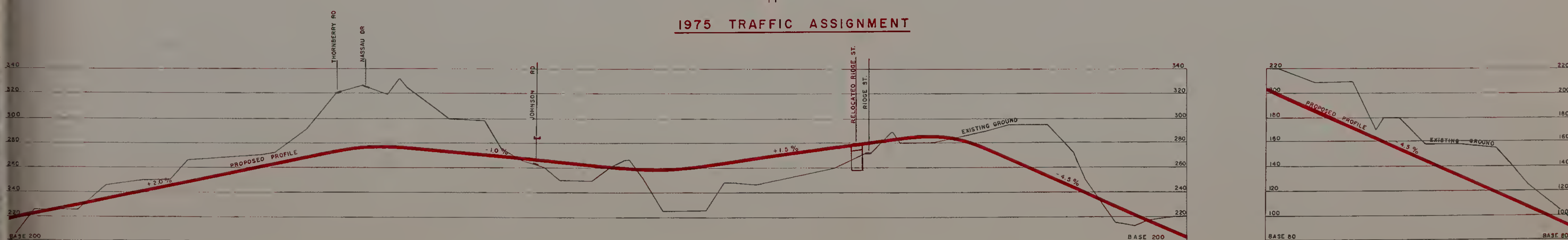
ALTERNATE LOCATION

ROUTE 128 TO WOBURN STREET

BURLINGTON-WOBURN-LEXINGTON



1975 TRAFFIC ASSIGNMENT



WOBURN STREET TO MYSTIC STREET

LEXINGTON-WINCHESTER-ARLINGTON

HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

ROUTE 3 EXPRESSWAY

ALTERNATE LOCATION

ROUTE 3 EXPRESSWAY

ALTERNATE LOCATION

MYSTIC STREET TO ALEWIFE BROOK PARKWAY

ARLINGTON-MEDFORD-SOMERVILLE

NORTHWEST-NORTHERN CONNECTOR
FREMONT STREET TO MAIN STREET
ARLINGTON-SOMERVILLE-MEDFORD

ROUTE 3 EXPRESSWAY
ALTERNATE LOCATION

ROUTE 3 EXPRESSWAY — NORTHWEST EXPRESSWAY

ALTERNATE LOCATION

HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

NORTHWEST-NORTHERN CONNECTOR
FREMONT STREET TO SHERMAN STREET

ARLINGTON-SOMERVILLE-CAMBRIDGE

SHERMAN STREET TO WEBSTER AVENUE

CAMBRIDGE-SOMERVILLE

HORIZONTAL SCALE 400 0 400 800

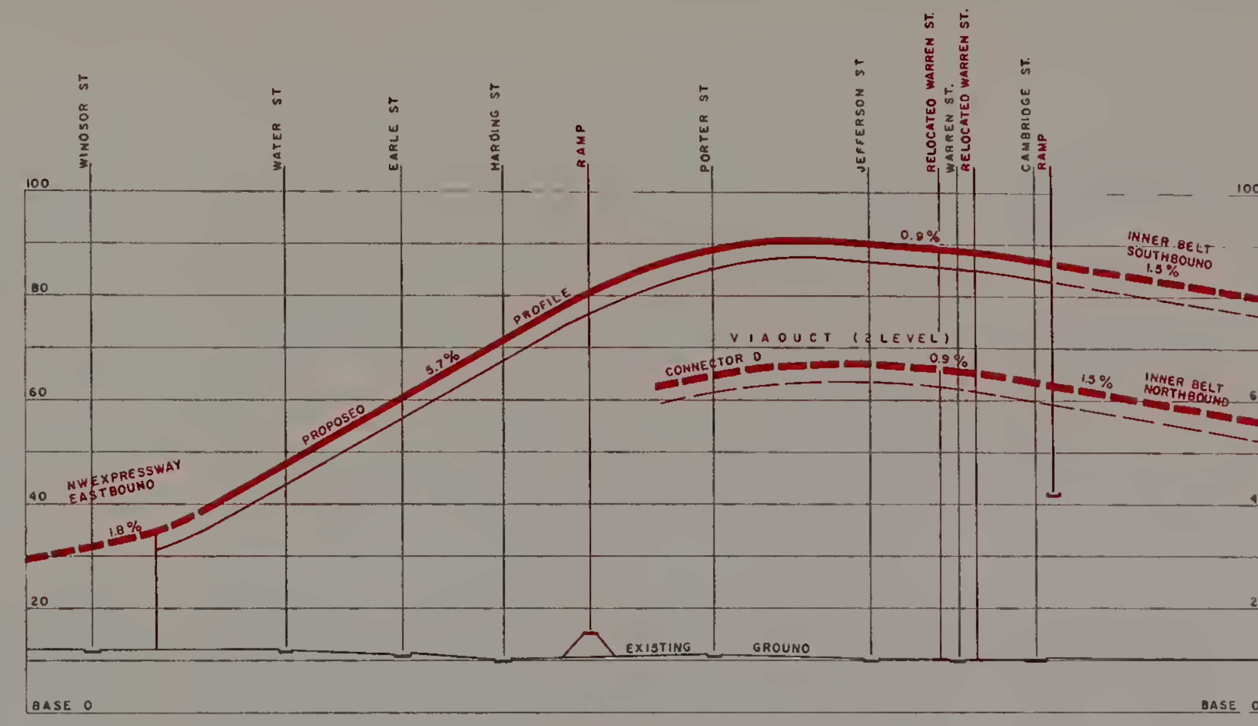
VERTICAL SCALE 40 0 40 80

SCALE IN FEET

NORTHWEST EXPRESSWAY

ALTERNATE LOCATION

CONNECTOR A



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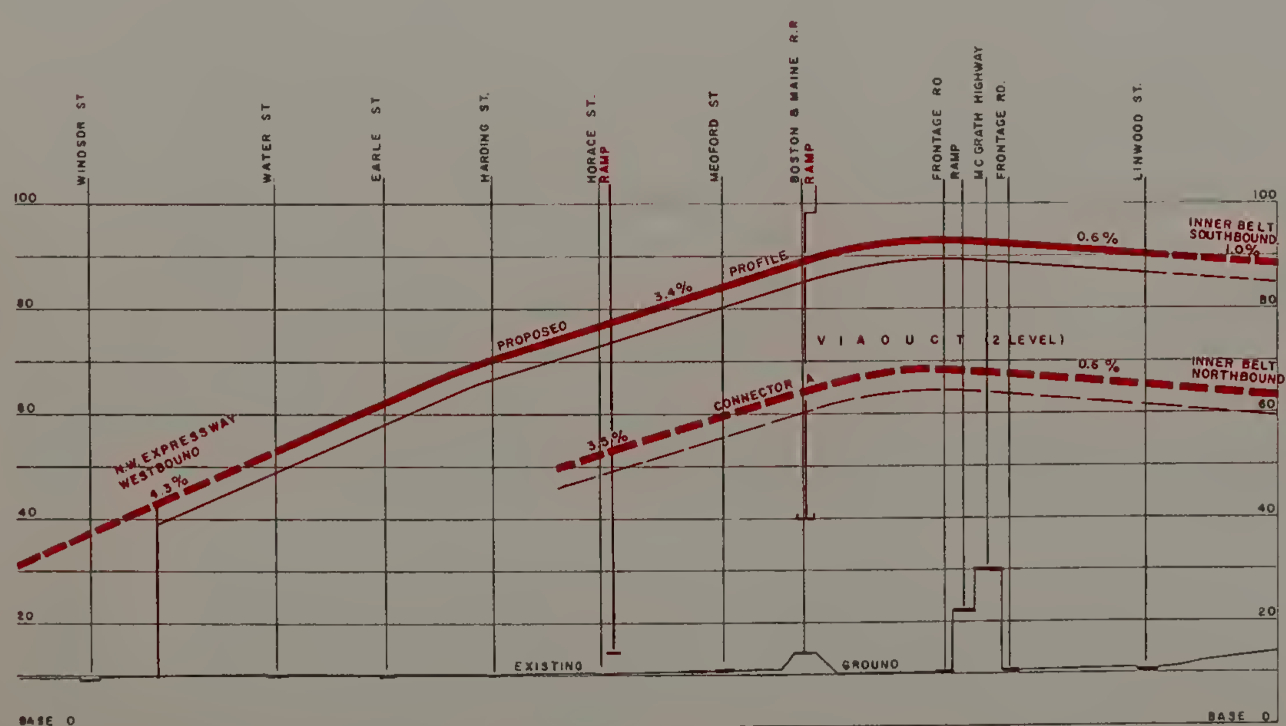

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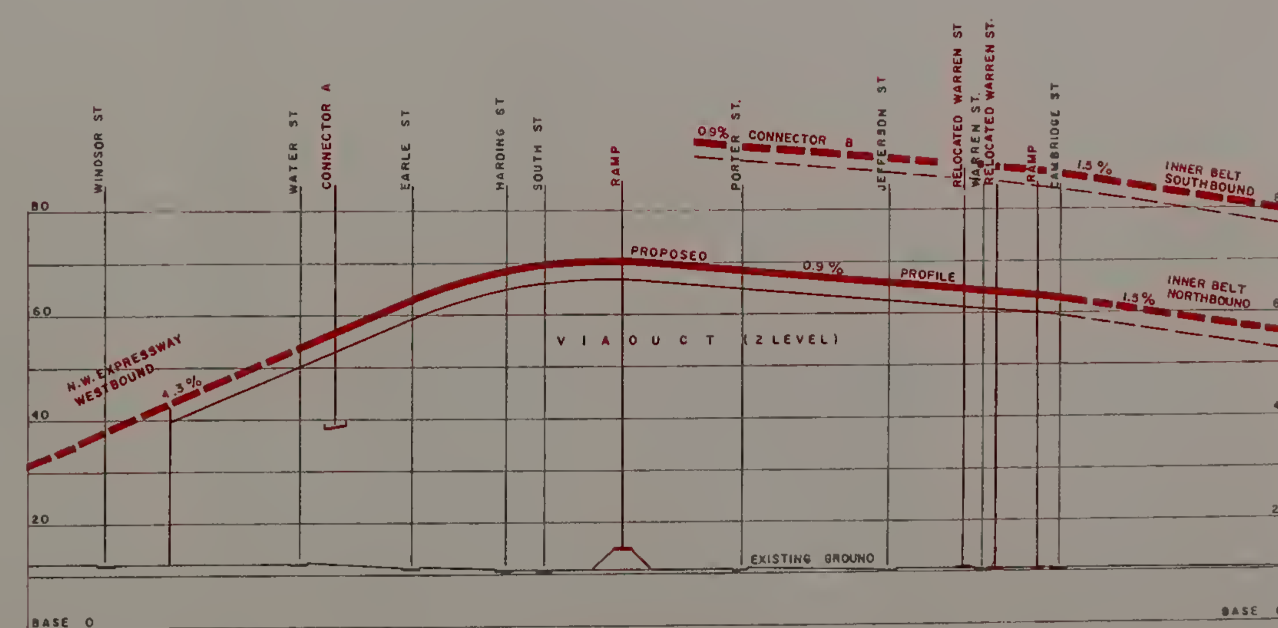


CONNECTOR D

NORTHWEST EXPRESSWAY AND INNER BELT

ALTERNATE LOCATION

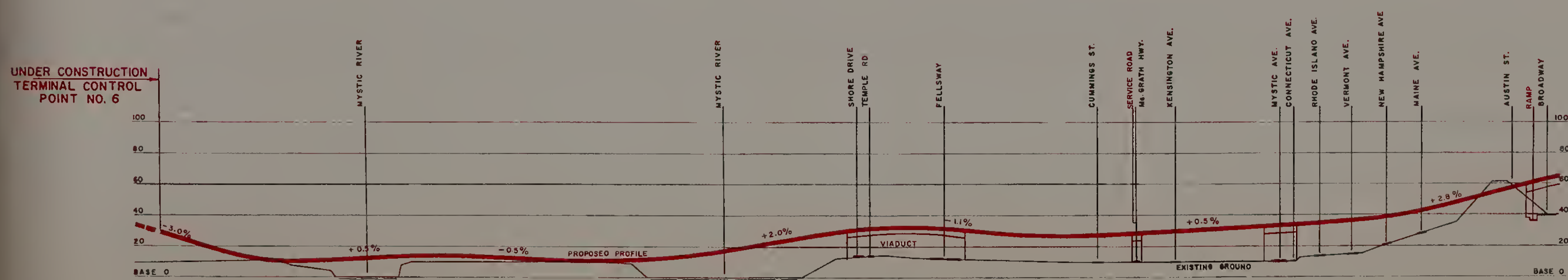
HORIZONTAL SCALE 200 0 200 400
VERTICAL SCALE 20 0 20 40
SCALE IN FEET

INTERCHANGE PROFILES
CAMBRIDGE-SOMERVILLE

INTERCHANGE PLAN
CAMBRIDGE-SOMERVILLE

NORTHWEST EXPRESSWAY AND INNER BELT
ALTERNATE LOCATION

1975 TRAFFIC ASSIGNMENT



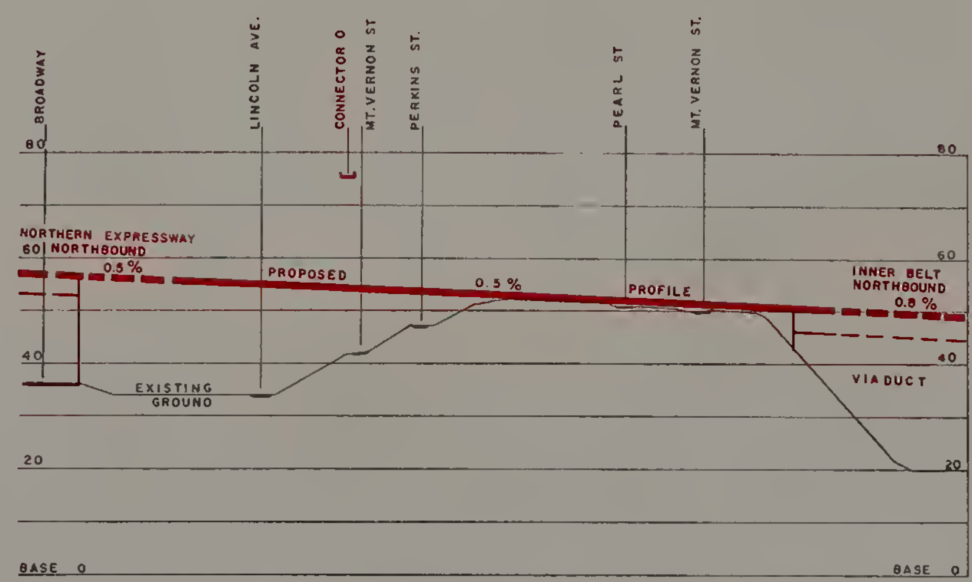
MYSTIC VALLEY PARKWAY TO BROADWAY

MEDFORD-SOMERVILLE

HORIZONTAL SCALE 400 0 400 800
VERTICAL SCALE 40 0 40 80
SCALE IN FEET

NORTHERN EXPRESSWAY

ALTERNATE LOCATION



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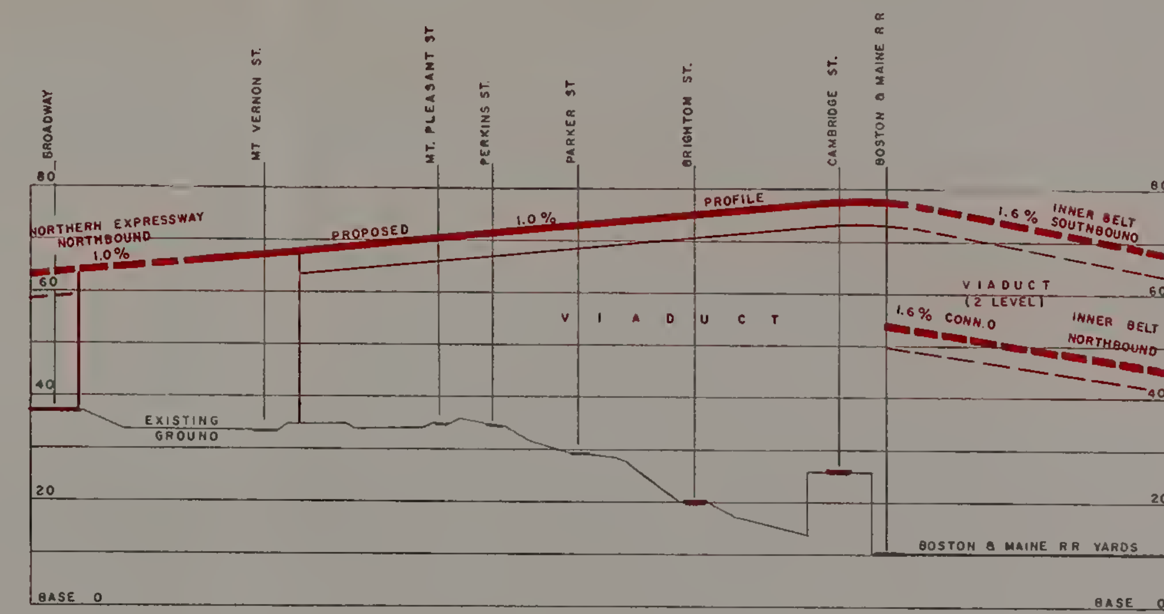

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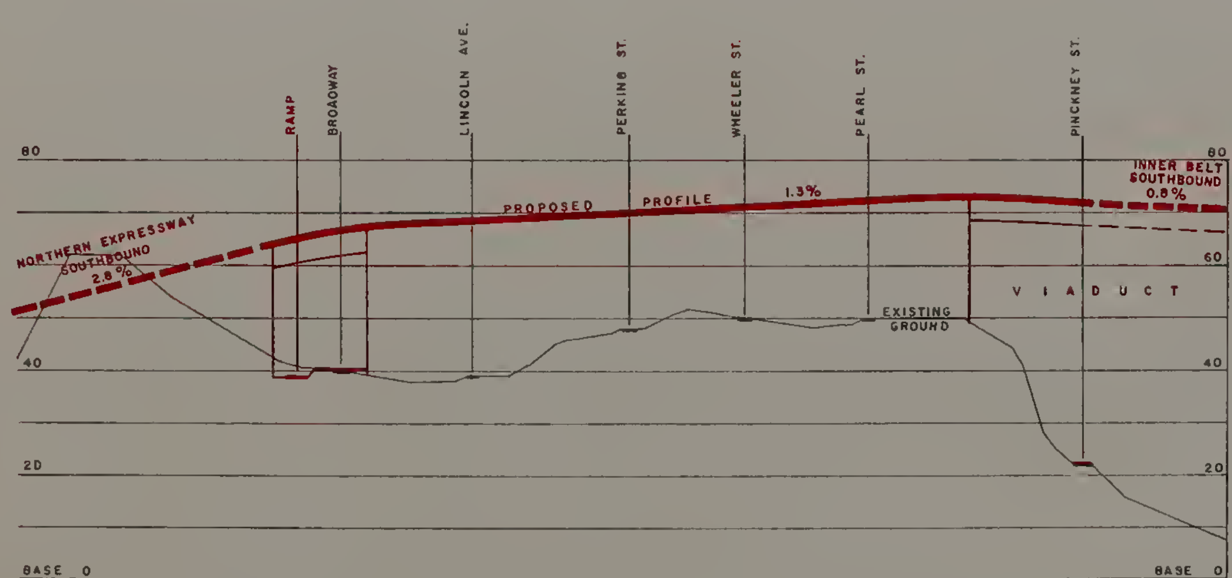

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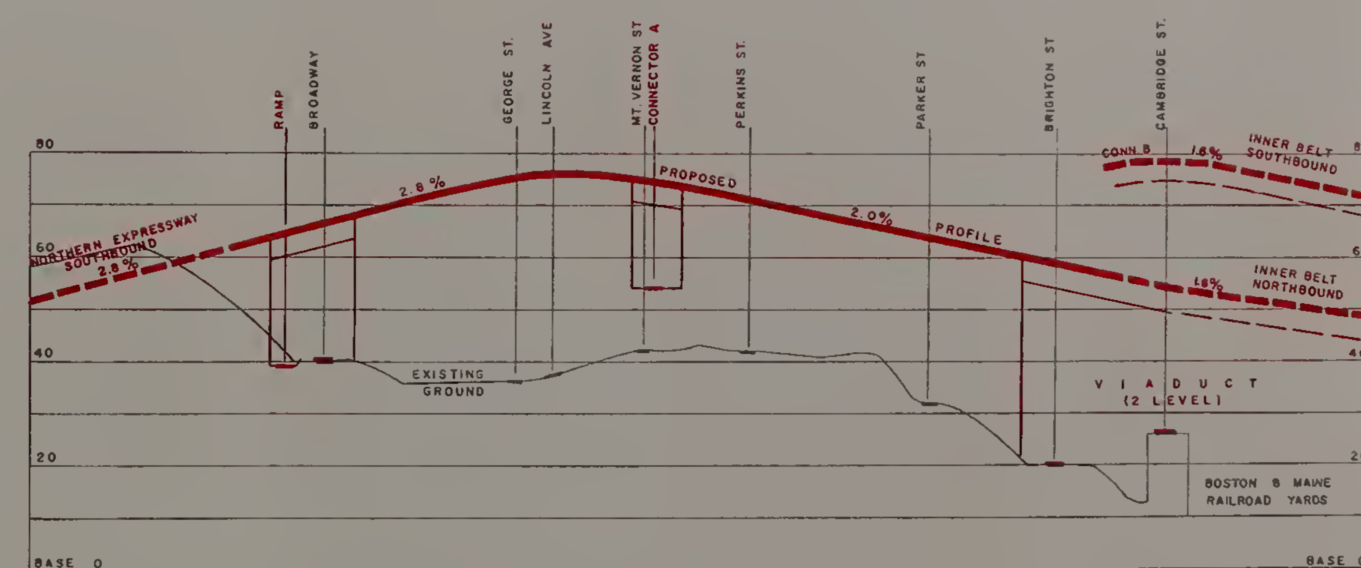

CONNECTOR D

NORTHERN EXPRESSWAY AND INNER BELT

ALTERNATE LOCATION

HORIZONTAL SCALE 200 0 200 400
VERTICAL SCALE 20 0 20 40
SCALE IN FEET

INTERCHANGE PROFILES
SOMERVILLE-BOSTON

SEE EXHIBIT NO. B-61

SEE EXHIBIT NO. B-43

SEE EXHIBIT NO. B-44

INTERCHANGE PLAN
SOMERVILLE-BOSTON

HORIZONTAL SCALE 200 0 200 400
VERTICAL SCALE 20 0 20 40
SCALE IN FEET

NORTHERN EXPRESSWAY AND INNER BELT
ALTERNATE LOCATION

PART II
REFERENCES

1. Road User Benefit Analysis for Highway Improvements, American Association of State Highway Officials, Washington, D.C. (1960) p. 10.
2. Bone, A. J., and Memmott, F. W., Travel Time Studies in Boston — 1960, M.I.T. — Massachusetts Department of Public Works Joint Highway Research Report No. 35, Boston, Mass. (1960).
3. Hoch, I., "Benefit-Cast Methods for Evaluating Expressway Construction," Traffic Quarterly, Eno Foundation for Highway Traffic Control, Saugatuck, Conn. (Apr. 1961).

PART III
REFERENCES

1. "Algorithm for Finding Shortest Paths Between Pairs of Points in a Network," Armour Research Foundation Phase Report No. 1 to the Chicago Area Transportation Study (June, 1957).
2. Anderson, T. R., "Intermetropolitan Migration," American Sociological Review, Vol. 20 (June 1955) pp. 287-91.
3. ...., "Potential Models and Spatial Distribution of Population," Papers and Proceedings of the Regional Science Association, Vol. 2 (1956).
4. Bevis, W., "A Model for Predicting Urban Travel Patterns," Journal of the American Institute of Planners, Special Issue, Vol. XXV, No. 2 (May 1959) pp. 87-89.
5. Blumenfeld, H., "Are Land Use Patterns Predictable?", Journal of the American Institute of Planners, Vol. XXV, No. 2 (May 1959).
6. ...., "On the Concentric-Circle Theory of Urban Growth," Land Economics (May 1949).
7. ...., "Correlation Between Value of Dwelling Units and Altitude," Land Economics (Nov. 1948).
8. ...., "The Dominance of the Metropolis" (comment), Land Economics (May, 1950).
9. ....,"The Tidal Wave of Metropolitan Expansion," Journal of the American Institute of Planners, Vol. XX, No. 1.
10. Bogue, J., The Structure of the Metropolitan Community, A Study of Dominance and Subdominance, University of Michigan, Ann Arbor (1949).
11. Bone, A. J., "Travel Time and Gasoline Consumption Studies in Boston," Proceedings of the 32nd Annual Meeting of the Highway Research Board, Washington, D.C. (Dec. 1951).
12. Bone, A. J., and Memmott, F. W., "Travel Time Studies in Boston — 1960," M.I.T. — Massachusetts Department of Public Works Joint Highway Research Report No. 35, Boston, Mass. (1960).
13. Bright, M. L., and Thomas, D. S., "Interstate Migration and Intervening Opportunities," American Sociological Review, Vol. 6 (Dec. 1941) pp. 773-83.
14. Brokke, G. E., and Mertz, W. L., "Evaluating Trip Forecasting Methods with an Electronic Computer," Public Roads, Vol. 30, No. 4 (Oct. 1958); also in: Highway Research Board Bulletin 203 (1959).
15. Brokke, G. E., "Assigning Traffic to a Highway Network," Public Roads, Vol. 30, No. 10, Washington, D.C. (Oct. 1959), p. 228.
16. ...., "Program for Assigning Traffic to a Highway Network," Trip Characteristics and Traffic Assignment, Highway Research Board Bulletin 224, Washington, D.C. (1959) pp. 89-90.
17. Colland, W. B., "Traffic Forecasting & Origin-Destination Trip Assignment Techniques," Proceedings of the Institute of Traffic Engineers, Western Section, 1958.
18. ...., "Forecasting Traffic for Freeway Planning," Journal of the American Institute of Planners, Vol. XXV, No. 2 (May 1959).
19. Campbell, E. W., "A Mechanical Method for Assigning Traffic to Expressways," Traffic Assignment by Mechanical Methods, Highway Research Board Bulletin 130, Washington, D.C., (1956) p. 40.
20. Carroll, J. D., Jr., "A Method of Traffic Assignment to an Urban Network," Trip Characteristics and Traffic Assignment, Highway Research Board Bulletin 224, Washington, D.C. (1959) p. 68.
21. Carrothers, A. P., "An Historical Review of the Gravity and Potential Concepts of Human Interaction," Journal of the American Institute of Planners, Vol. XXII, No. 2 (Spring, 1956) pp. 94-102.
22. Cavanaugh, J. A., Formulation, Analysis, and Testing the Interactance Hypothesis, unpublished thesis, University of Washington Library, Seattle (1950).
23. Chicago Area Transportation Study, Final Report, Vol. II, Chicago, Ill. (Jul. 1960) p. 107 et seq.
24. Christaller, W., Die Zentralen Orte in Suddeutschland, Gustav Fischer, Jena, Germany, (1933).
25. Clark, C., "Population Movements into the Outer Suburbs of Large Cities — Measurements and Prediction," Report of Proceedings, Town and Country Planning Summer School, Town Planning Institute, University of Bristol, London (1953).
26. ...., "Transportation, Maker and Breaker of Cities," The Town Planning Review (Jan. 1958).
27. ...., "Urban Population Densities," Journal of the Royal Statistical Society, Vol. CXIV, Part IV (1951) pp. 490-96.
28. Dodd, S. C., "The Interactance Hypothesis: A Gravity Model Fitting Physical Masses and Human Groups," American Sociological Review, Vol. 15, No. 2 (Apr. 1950) pp. 245-56.
29. Duncan, O. D., "Population Distribution and Community Structure," Cold Spring Harbor Symposium on Quantitative Biology, Vol. 22 (1957).
30. Dunn, E. S., "The Market Potential Concept and the Analysis of Location," Papers and Proceedings of the Regional Science Association, Vol. 2 (1956).
31. Fisher, F., and Fleischer, G., Study of Traffic Operations on Massachusetts Route 128, unpublished thesis, M.I.T. Library, Cambridge, Mass. (1958).
32. Fratar, T. J., "Vehicular Trip Distribution by Succession Approximations," Traffic Quarterly (Jan. 1954).
33. Gill, J. D., and McCarthy, A. J., Travel Time Study on John F. Fitzgerald Expressway vs. Parallel City Streets, unpublished thesis, M.I.T. Library, Cambridge, Mass. (1956).
34. Hoffman, W., Moyer, A., Pavley, R., and Smack, R., "Describing Travel Patterns in Large Cities," Detroit Area Traffic Study, Wayne State University (1959).
35. Hoffman, W., and Pavley, R., "A Method for the Solution of the N-th Best Path Problem," Journal of the Association for Computing Machinery (1959).
36. Isard, W., "Distance Inputs and the Space-Economy, Part 1, The Conceptual Framework," The Quarterly Journal of Economics, 65 (May 1951) pp. 181-191.
37. ...., "Distance Inputs and the Space-Economy, Part 2, The Location Equilibrium of the Firm," The Quarterly Journal of Economics, 65 (Aug. 1951) pp. 373-399.
38. ...., Location and Space-Economy, The Technology Press, Cambridge (1956).
39. ...., "Location Theory and Trade Theory: Short-Run Analysis," The Quarterly Journal of Economics, Vol. 68 (May 1954) pp. 305-320.
40. Isbell, E. C., "Internal Migration in Sweden and Intervening Opportunities," American Sociological Review, Vol. 9 (Dec. 1944) pp. 627-39.
41. Killen, E. L., "Highway-Traffic Estimation by Linear Programming," Journal of the Highway Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. HW1, Port 1 (Jan. 1959) pp. 17-33.
42. Kurz, C. R., and Powell, T. E., Study of Highway Travel Conditions in Metropolitan Boston, unpublished thesis, M.I.T. Library, Cambridge, Mass. (1948).
43. Laesch, A., Die Naeumliche Ordnung der Wirtschaft, Second Edition, G. Fischer, Jena, Germany, (1944) pp. 70-71, 307-16.
44. ...., The Economics of Location, Yale University Press, New Haven (1954) Table 21.
45. Lynch, J. T., "Home-Interview Surveys & Related Research Activities," Trip Characteristics and Traffic Assignment, Highway Research Board Bulletin 224 (1959).
46. McKenzie, R. D., The Metropolitan Community, New York (1933).
47. Mertz, W. L., "Traffic Assignment to Street and Freeway Systems," Traffic Engineering, Vol. 30, No. 10 (Jul. 1960) p. 27.
48. Moore, E. F., "The Shortest Path Through a Maze," International Symposium on the Theory of Switching, Harvard University, Cambridge (1957).
49. Moskowitz, K., "California Method of Assigning Diverted Traffic to Proposed Freeways," Traffic Assignment by Mechanical Methods, Highway Research Board Bulletin 130 (1956).
50. Mylroie, W., "Evaluation of Intercity-Travel Desire," Highway Research Board Bulletin 119 (1956) pp. 69-94.
51. A Policy on Arterial Highways in Urban Areas, American Association of State Highway Officials, Washington, D. C. (1957) pp. 10, 95 et seq.
52. Ravenstein, E. G., "The Laws of Migration," Journal of the Royal Statistical Society, Vol. 48 (Jun. 1885) pp. 167-227, and Vol. 52 (Jun. 1889) pp. 241-301.
53. Reilly, W. J., "Methods for the Study of Retail Relationships," University of Texas Bulletin No. 2944 (Nov. 1929).
54. ...., The Law of Retail Gravitation, Second Edition, Filsburg Publishers, New York (1953).
55. Report on the Detroit Metropolitan Area Traffic Study, Part II, Detroit, Mich. (Mar. 1956) pp. 80, 81.
56. Rivard, L. A., "Electronic Traffic Projection and Assignment," Report of Meetings of the A.A.S.H.O. Electronics Committee, Boston, 1959, Washington, D.C. (1959) p. 44.
57. Row and Jurkat, "The Economic Forces Shaping Land Use Patterns," Journal Of The American Institute Of Planners, Vol. XXV, No. 2 (May 1959).
58. Schmidt, R. E. and Campbell, M. E., Highway Traffic Estimation, Eno Foundation for Highway Traffic Control, Saugatuck, Conn. (1956) p. 135.
59. Silver, J., "Trends in Travel to the Central Business District by Residents of the Washington, D.C., Metropolitan Area, 1948 and 1955," Trip Characteristics and Traffic Assignment, Highway Research Board Bulletin 224, Washington (1959) pp. 1-40.
60. Smith, Wilbur, & Associates, Future Highways and Urban Growth, Automobile Manufacturers Association, New Haven, Conn. (1961) p. 174.
61. Stewart, J. Q., "An Intense Distance Variation for Certain Social Influences," Science N. S., 93 (1941) p. 89.
62. ...., "Empirical Mathematical Rules Concerning the Distribution and Equilibrium of Population," Geographical Review, Vol. XXXVII (Jul. 1947) pp. 461-85.
63. ...., "Demographic Gravitation: Evidence and Application," Sociometry, Vol. XI (Feb.-May 1948) pp. 31-58.
64. ...., "Concerning Social Physics," Scientific American, Vol. 178 (May 1948) p. 22.
65. ...., "The Development of Social Physics," American Journal of Physics, Vol. 18 (May 1950) pp. 239-53.
66. ...., "Potential of Population and its Relationship to Marketing," Theory in Marketing, edited by R. Cox and W. Alderson, Chicago (1950) pp. 19-40.
67. Stouffer, S. A., "Intervening Opportunities: A Theory Relating Mobility and Distance," American Sociological Review, Vol. 5 (Dec. 1940) pp. 845-67.
68. The Structure and Growth of Residential Neighborhoods in American Cities, Federal Housing Administration, Washington, D.C. (1939) p. 114.
69. "Travel in the Boston Region, 1959-1980," Studies of Urban Transportation, Boston College Seminar Research Bureau, 1960-61.
70. Ullman, E., "A Theory of Location for Cities," American Journal of Sociology, Vol. XLVI (May 1941) pp. 853-64.
71. Vining, R., "Delimitation of Economic Areas; Statistical Conceptions in the Study of the Spatial Structure of an Economic System," Journal of The American Statistical Association, Vol. 48 (Mar. 1953) pp. 44-64.
72. ...., Economic Development and Cultural Change, Vol. III (Jan. 1955) pp. 196-198.
73. Wood, G., "Traffic Assignment by IBM," Traffic Quarterly, Eno Foundation for Highway Traffic Control, Saugatuck, Conn. (Apr. 1961) p. 331.
74. Voorhees, A. M., and Morris, R., "Estimating and Forecasting Travel for Baltimore by Use of a Mathematical Model," Trip Characteristics and Traffic Assignment, Highway Research Board Bulletin 224, Washington (1959) pp. 105-114.
75. Voorhees, A. M., "A General Theory of Traffic Movement," Proceedings, Institute of Traffic Engineers (1959).
76. ...., "The Nature & Uses of Models in City Planning," Journal of the American Institute of Planners, Vol. XXV, No. 2 (May 1959).
77. ...., "Use of Mathematical Models in Estimating Travel," Proc. ASCE, Vol. 85, HW4, Part 1 (Dec. 1959).
78. Zipf, G. K., "The Unity of Nature, Least Action, and Natural Social Science," Sociometry, Vol. 5 (Feb. 1942).
79. ...., "The P_1P_2/D Hypothesis: the Case of Railway Express," Journal of Psychology, Vol. 22 (Jul. 1946) pp. 3-8.
80. ...., "The P_1P_2/D Hypothesis: on the Intercity Movement of Persons," American Sociological Review (Dec. 1946).
81. ...., Human Behavior and The Principle of Least Effort, Addison-Wesley Press, Cambridge (1949).

PART IV
REFERENCES

1. Banker & Tradesman, Warren Publishing Carp., Boston, Mass., Vol. CXXXVII, No. 31, to Vol CXXXIX, No. 9, Aug. 2, 1958-Feb. 27, 1960; values estimated at the rate of $1.10 tax stamps per $1000 selling price.
2. Bone, A. J. and Wohl, M., Economic Impact Study of Massachusetts Route 128, Massachusetts Institute of Technology, Cambridge, Mass., 1958.
3. Gery, F. W., New England Business Review, Boston Federal Reserve Bank, Boston, Mass., August 1959.
4. Third Progress Report of the Highway Cost Allocation Study, House Document No. 91, 86th Congress, 1st Session, 1959.
5. Johnson, R., An Analysis of the Changing Pattern of Massachusetts Manufacturing Production and Jobs, 1960-1970, Associated Industries of Massachusetts, Boston, Mass., 1959.
6. Jurkat, E., Baltimore Central Business District Projections, Marketers Research Service, Inc., May 1959 (Mimeo).
7. Long Range Projections for Economic Growth in the American Economy Through 1970, Notional Planning Association, Washington, D.C., 1959.
8. Sweetser, F. L., The Population of Greater Boston Projected to 1970, Greater Boston Economic Study Committee, Boston, Mass., June 1959.

SELECTED BIBLIOGRAPHY

Balfour, F. C., "California's Land Economic Studies Along Controlled Access Highways," Traffic Quarterly, Vol 1:1, January 1958.

Garrison, W. L., Berry, B. J. L., Marble, D. F., Nystuen, J. O., Morrill, R. L., Studies of Highway Development and Geographic Change, University of Washington Press, Seattle, Wash., 1959, pp. 20-35.

Isard, W. and Coughlin, R., Municipal Costs and Revenues Resulting from Community Growth, Chandler Davis Publishing Co., Wellesley, Massachusetts, 1957.

Johnston, W. W., "Travel Time and Planning," Traffic Quarterly, January 1956, Vol. 10:1 pp. 67-68.

U. S. Dept. of Commerce, U. S. Income and Output, Washington, D. C., 1959

U. S. Dept. of Labor, Bureau of Labor Statistics, Population and Labor Force Projections for the United States 1960-1975, Bulletin 1242, Washington, D.C., 1959.

Von Bertalanffy, L., General System Theory: A New Approach to the Unity of Science, 47th Annual Meeting of American Philosophical Association, Eastern Division, Toronto, Canada, December 1950.

Warner, A. E., The Impact of Highways on Land Use and Property Values, Highway Traffic Safety Center, Michigan State University, March 1958.

Warner, W., Residential Redevelopment of the West End of Boston, unpublished thesis, M. I. T. Library, Cambridge, Mass. (1958).

Wheaton, L. C. and Schussheim, M. L., The Cost of Municipal Services in Residential Areas, U. S. Housing and Home Finance Agency, 1953.